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Improving multimodal web accessibility for deaf people: sign language interpreter module

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Abstract The World Wide Web is becoming increasingly necessary for everybody regardless of age, gender, culture, health and individual disabilities. Unfortunately, there are evidently still problems for some deaf and hard of hearing people trying to use certain web pages. These people require the translation of existing written information into their first language, which can be one of many sign languages. In previous technological solutions, the video window dominates the screen, interfering with the presentation and thereby distracting the general public, who have no need of a bilingual web site. One solution to this problem is the development of transparent sign language videos which appear on the screen on request. Therefore, we have designed and developed a system to enable the embedding of selective interactive elements into the original text in appropriate locations, which act as triggers for the video translation into sign language. When the short video clip terminates, the video window is automatically closed and the original web page is shown. In this way, the system significantly simplifies the expansion and availability of additional accessibility functions to web developers, as it preserves the original web page with the addition of a web layer of sign language video. Quantitative and qualitative evaluation has demonstrated that information presented through a transparent sign language video increases the users' interest in the content of the material by interpreting terms, phrases or sentences, and therefore facilitates the understanding of the material and increases its usefulness for deaf people.

Keywords Human-computer interaction · Usability · Accessibility · Deaf and hard of hearing · Sign language · Video · Transparent video

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1 Introduction

Information and Communications Technology (ICT), with its applications and systems, such as the World Wide Web (the Web), has contributed significantly to the potential for improving the status of people with disabilities in the social and socio-occupational area. Every day, millions of people use it as an effective tool for communication and information gathering. For example, one can witness the increased introduction of sophisticated multimedia computer presentations together with options for audio and video communication.

Despite web applications being so interesting, there is an increasing risk that people with disabilities could be forced into a subordinate position. Surveys, such as the United Nations Motivation Global Audit of Web Accessibility in 2006, showed that in 20 countries around the world, only 3 of the 100 entry web pages have reached the base level of accessibility [39]. In this study, it was found that some web sites could easily be upgraded with at least the basic interactive elements essential for meeting the requirements and needs of people with disabilities. The entry web page of each web site was evaluated on the basis of the globally recognized recommendations titled Web Content Accessibility Guidelines version 1.0 (WCAG 1.0), published by the Web Accessibility Initiative (WAI) [3, 43].

In addition to WCAG guidelines, guidelines for the accessibility of material on the Web were also released by other international standards organizations such as the International Telecommunication Union (ITU) and the International Organization for Standardization (ISO). Unfortunately, these guidelines are still too general and often inadequate and inappropriate for the specific needs of people with disabilities, such as deaf people who use sign language as their first language. This group mainly offers a solution in written form, such as through the conversion of speech or sound into written text, such as subtitles. For the vast majority of deaf people, who communicate in sign language, text written in a language they consider to be their second language is difficult to comprehend. The inadequacy of existing guidelines was also reflected in research of usability evaluation by Ivory and Hearst [22], who conclude that automation of usability evaluation does not capture important qualitative and subjective information and propose analytical and simulation modeling before web site development.

On the other hand, the development and increasing speed of data transmission over the Internet opens additional possibilities for the transfer of more complex applications, such as high quality video, audio, animations and simulations transmission, which could be one basis for improving the accessibility of materials for people with disabilities [40]. However, despite the development of broadband connections, the material on the Web still relays too many text documents and static images rather than videos, which is, unfortunately, inappropriate for the majority of deaf and hard-of-hearing people who use sign language as their first language. Past research has shown that deaf signer users, who use sign language as a first and desired language, are often helpless and become confused when searching for information on web sites [6, 10].

To help web designers develop sites with greater accessibility, we have provided the following solutions for deaf users utilizing video technology.

- The presentation of transparent sign language videos on existing web pages to describe part or all of the available material.
- The control of the video (size and speed adjustment, pause and stop).

The objective was to enhance the accessibility of web sites for the deaf so that there would be no need for a double online system (in the native language and in sign language), but to use existing materials with an accessibility update to sign language video.

This study demonstrates, by both quantitative and qualitative evaluations, that information presented through a transparent sign language video increases the users' interest in the content of materials by interpreting terms, phrases or sentences, and therefore facilitates the understanding of the material and increases its usefulness for deaf people.

This enables deaf people to be even better prepared to read other related texts [5]. Moreover, we show that a transparent web video enables web designers to use the existing design in place and add appropriate interactive elements that trigger sign language videos on the web sites. Our theory is confirmed by the results of the experiment.

In Section 2, we describe the problem of hearing loss and motivation for the use of sign language video. In Section 3, we describe related works in this field. In Section 4, we analyze the video requirements for deaf and hard-of-hearing users. The main features of our system and implementation process are presented in Section 5. In Section 6, we present the design and realization of a prototype tested during evaluation. Section 7 reveals the results and findings from the experiment. In Section 8, we conclude with final thoughts and one further research work proposal.

2 Hearing loss and motivations for sign language video

The loss or deterioration of hearing occurs when problems arise with the perception of such sound elements as frequency, pitch, timbre and loudness of the surroundings. Hearing loss is generally classified in terms of different categories of dB (decibels) loss, such as mild hearing loss (between 25 and 40 dB), moderate hearing loss (between 40 and 70 dB), severe hearing loss (between 70 and 95 dB) and profound hearing loss (from 95 dB onwards) [25]. Types of hearing loss may be conductive, sensorineural, mixed or central. Conductive hearing loss occurs when sound conduction is lost from the outer and middle ear in the inner ear, which may occur due to chronic middle ear infections or diseases. Sensorineural hearing loss results from damage to hair cells in the cochlea in the inner ear. This happens due to the long exposure to loud noise, diseases (e.g. meningitis) or the use of certain drugs such as the antibiotics streptomycin and gentamicin.

Some deaf people, but not all, use full natural language to communicate among themselves, which is known as sign language. Sign language for deaf people is based on hand movements, face, eyes and lips mimicry, and body movement. It uses a visual-sign system with defined positions, locations, orientations and movements of hands and fingers, as well as facial expressions.

Sign language also has its own linguistic structure, independent of the vocal language in the same geographical area. Word order (which is different from written language) and grammatical structure are a product of the separate development of a physical language within the deaf community.

This method of communication has a strong impact on the culture and language of the deaf community and the individuals within that community. In the case of hearing loss (deafness), we are therefore talking about two cultures and two languages.

Since deaf people frequently use sign language, with its lack of sound and constant visual communication, they face difficulties accessing written text in web content and web applications, placing them at a disadvantage.

There are several arguments and motivations for providing sign language video on the Web.

- Demographics data.
- Literacy and access to information.
- Reading ability.
- Navigation ability.
- Multilanguage requirements.

2.1 Demographics data

Studies by international organizations have shown that there are around 650 million people with some form of disability, representing almost 10% of the total population in the world. Around 28 million people living in the United States have a certain degree of hearing loss [13, 17, 26]. In the European Union, the tendency towards an aging population is apparent and is expected to be associated with an increase in the number of people suffering from hearing loss.

According to research by the Institute of Hearing Research (IHR) in the UK and according to the survey of Shiel (2006) [31], approximately 71 million people worldwide had a degree of hearing loss in 2005.

World Health Organization (WHO) estimates a probable 90 million people in 2015 will be living with some degree of hearing loss greater than 25 dB, due to the aging of the population. About 4 million people in the European Union are reported as profoundly deaf. With regard to children, the IHR estimates that there are 174,000 children in Europe as a whole with severe hearing loss and another 600,000 with mild hearing loss. These statistics make the hearing-disabled population one of the largest minorities facing the challenge of communication that is mainly audio-based [2].

2.2 Literacy and access to information

Based on data collected by the World Federation of the Deaf (WFD), around 80% of deaf people worldwide have an insufficient education and/or literacy problems, lower verbal skills and mostly chaotic living conditions [45]. Other research shows that deaf people are often faced with the problem of acquiring new words and notions [25, 27]. Because of the many grammar differences between their mother tongue and sign language, the deaf person might be fluent in sign language while experiencing problems reading their mother tongue. According to Holt, the majority of deaf 18-year-olds in the United States have poorer reading capabilities of English in comparison to 10-year-old students who are not deaf [18].

Some studies that have examined the reading ability of deaf 16-year-olds have shown that about 50% of the children are illiterate. Of these, 22% displayed a level of knowledge equivalent to that of a 10-year-old child who is not deaf and only 2.5% of participants actually possessed the reading skills expected for their age [14]. Also, other studies in the United States by Farwell have shown that deaf people face difficulties when reading written text [11]. The average literacy rate of a high school graduate deaf student was similar to that of a non-deaf student in the third or fourth grade.

Access to information is also important in cases of emergency. Past disasters around the world have shown that, at the time of an accident, people with disabilities did not receive the same assistance and appropriate information as other people did.

The United Nation Convention [38] calls upon States to develop measures for emergency services (article 9 (1) (b)). Messages using video for deaf people have rapidly become one of the more popular methods for sending them information but, unfortunately, most countries' emergency services do not allow for video communications with deaf people. The reason lies in the communication protocols, which are not compatible with each other.

2.3 Reading ability

It is surprising and disappointing that many deaf and hard-of-hearing people, particularly those for whom sign language is the first language, have reading difficulties [13].

The problem arises because writing was developed to record spoken language and therefore favours those with the ability to speak. Spoken language contains phonemes which can be related to the written word by mind modelling. Due to the lack of audible components and consequently difficulties in understanding written words, this can not be done by deaf people. However, this is not applicable for all, because some completely deaf people become excellent readers, while even people with lower hearing loss may have difficulties with reading. Depending on their education and the social community, some deaf people use lip-reading for easier communication and assistance in learning to read.

According to Hanson [13], the language experience for each deaf or hard of hearing individual *is not implicit* because it is about different personal knowledge and skills, such as sign language, clear speaking, lip-reading and textual reading. This knowledge has implications for web designers who have to use sign language videos to meet the needs of deaf and hard-of-hearing users.

2.4 Navigation ability

Another motivation for the integration of sign language videos into web sites is that sign language improves the taxonomic organization of the mental lexicons of deaf people. The use of sign language on the Web would, in this case, reduce the requirements for the rich knowledge of the words and notions of another language. A knowledge of words and notions is of the utmost importance for navigation in and between web sites and for the use of hyperlinks, such as in online shopping web sites where a lot of different terms and sub-terms in vertical and horizontal categories appear. Unfortunately, deaf people have problems understanding the meaning of words and notions, especially when it is necessary to understand certain notions in order to correctly classify and thus understand either a word or another notion [25].

2.5 Multilanguage requirements

One of the important requirements is multilanguage support, especially in Europe. For example, tourist information, governmental and emergency service web designers need to construct web sites in English, German, Italian, French and even in Hungarian. This is particularly true for small countries such as Slovenia, which are surrounded by several countries with rich language backgrounds. In some countries sign language is also recognized as an *official national language*, and therefore there is a strong need to include sign language translations into web sites.

3 Related work

Several solutions exist which are designed for deaf and hard-of-hearing people with acknowledge of sign language, all of which share the integration of sign language videos into the web pages, which requires additional space for video. This method drastically reduces the area that can be used for the usual positioning of web material such as text, pictures and other multimedia elements.

In projects, such as SMILE [24], ShowSounds [41], Signing Web [12], ATBG [36], SignOn [16], History of the Deaf [6] and Signing Savvy for American Sign Language (ASL) [32] (that originates from the Sign Language Browser project from Stewart [37]), it is obvious that web sites must be carefully planned to position the video in exact locations on each web page.

The demand for the constant presence of video on the web site is, unfortunately, totally inadequate for classical informative web sites which cover huge amounts of daily information. The question that immediately arises here is this: *How can we solve the problem of including a sign language video clip without breaking the existing design of the web page, while at the same time, with the minimum coding, enabling the option to play the video clip?*

The basis of the idea for our project of transparent sign language video results from the method of creating a transparent background for Adobe Flash™ video and DHTML (Dynamic HyperText Markup Language) layers. On the one hand, the transparent background of the video gives the impression that the sign language interpreter is "cut", as the background of the video is not seen due to the transparency; on the other hand, DHTML allows the video to appear as an additional layer, which allows the structure of the web page to be preserved.

The previous work of other projects suggests that a similar idea has not yet been implemented for deaf people who use sign language as their primary language. Because of its simplicity and ease-of-use—adjusting a web site requires minimal changes—the solution could be integrated into "WCAG Guidelines" for the needs of deaf and hard-of-hearing people. Currently, the Web Content Accessibility Guidelines definition states that "using clear and simple language also benefits people whose first language differs from your own, particularly those people who communicate primarily with sign language" [44], and does not yet determine that transparent video should be used, which would allow for the rapid and easy integration of sign language videos.

In addition, other studies have shown that natural videos are more welcome and accepted by the end users than signing avatars and synthetic gestures [29]. Due to this fact, a higher value has been set on the video quality of the sign language interpreter.

Other studies have aimed at the use of technology to translate spoken words into sign language, such as surveys of Vogler [42], Bangham (project ViSiCAST) [1] or animation ASL generator by Huenerfauth [21], and eSign [9]. Although these translation methods may be appropriate for certain areas, the aim of our project was not translation or interpretation.

Instead of focusing on the translation between written/spoken words and sign language, we wanted to find an appropriate solution to simplify the design and implementation of sign language video clips as transparent videos over the existing web pages in a way that is friendly to users and authors. Our idea was to provide deaf people with a new option for easy and rapid access to information, tailored to their needs without discriminating against other users. In addition to this idea of a transparent video, we wanted to find a link between the existing elements of the page and the video translations. The missing link in this

communication is the transfer of the relevant sign language video, which may even be animated, from the web server (for example, the Sign Savvy portal) to existing web sites.

4 Requirement analysis: videos used by hearing impaired people

It is a fact that deaf and hard-of-hearing users whose first language is sign language require translations of the written text on web sites which are written in their second language. One of the limitations of providing such sign language videos is the high costs of producing, processing, saving and exchanging videos suitable for written parts, whether for single words or notions. Other obstacles are high demands and the requirements of making videos usable for all deaf and hard-of-hearing users, including the elderly [20].

The aspects listed below were determined based on the results of other research projects and the methodology of needs analysis as supported by the European Commission [34]. Those methods include personal interviews and brainstorming with end users, such as the directors of educational institutions, specialists for teaching people with special needs, and teachers who are also themselves people with special needs. There would also be questionnaires and the organization of discussion panels for brainstorming and feedback with the help of three workshops for teachers from educational institutions for people with special needs. These teachers also use ICT in the deaf educational process.

4.1 Web design requirements

Based on Web Content Accessibility Guidelines (WCAG 2.0), published by the Web Accessibility Initiative (WAI), web application design for deaf and hard-of-hearing users should contain a clear presentation of information and data (Guideline 1.4 Distinguishable: "Make it easier for users to see and hear content including separating foreground from background" [44]). In this segment one can find instructions and guidelines for colour, audio, contrast, resizing and images of text. However, there are no provided instructions or guidelines for sign language videos aside from those in Guideline 1.2 Time-based Media: "Provide alternatives for time-based media, which is designed to access to time-based and synchronized media on the Web".

Requirements for signing and subtitling are also defined in the EBU report on Access Services by the European Broadcasting Union (EBU) standard [8], which precisely defines recommendations for people with disabilities in the broadcasting industry. This report presents the recommendations for the broadcasting industry and it would be reasonable to transfer these recommendations to the Web.

At the moment, the most popular approach that web developers use for designing web sites for deaf and hard-of-hearing users is the integration of Adobe Flash Player into a specific section of the page where the sign language video is shown. The advantage of this approach is the cross-browser compatibility, and the lack of security issues but the obstacles include the fact that informative web sites frequently contain text, images and photos expanding throughout the whole page, leaving no space for the video. One of the possible solutions could be the use of a popup window, although this may interrupt user's visual contact/focus with the content beneath. Also, as a matter of security, some browsers prevent popup windows by default, and not all of our target users are sufficiently knowledgeable to tailor their settings accordingly. Other way of presenting the sign language videos include launching a local application player such as Windows Media Player™, RealPlayer™ or

QuickTime™. In this way, the designers confront difficulties since each player requires different implementation approaches.

Web portals aimed at deaf people are mostly designed to contain a sign language video constantly in a certain fragment of the web page, such as in Signing Savvy for ASL [32], online courses, like ECDL material developed within the DISNET project [7] and e-Learning material ATBG [36]. The video-sharing portal YouTube [46] is an example of an environment where video clips are created and represent the primary piece of information.

A needs analysis showed that the end users' main requirement was sign language videos, which should appear on-demand by clicking on the appropriate icon or on a multimedia element on the web site.

Consequently, our idea was to enable the preparation and embedding, of a sign language video with a link from any element of the web site, whether that be a word, a sentence, a paragraph or whole block of text, a picture, an animation or even another video clip.

4.2 Accessibility requirements

The basic aspects of accessibility set out in the needs analysis for sign language video have been divided into seven functionalities.

- Video control.
- Video image resizing.
- Adding subtitles.
- Slowing down the video.
- Shifting the video across the web page.
- Rapid display of the video.
- Adding sound for deaf and hard-of-hearing people.

The first, most simple aspect of accessibility is the ability to pause and stop video at any time whenever the clip is longer than 5 s (WCAG 2.0 Guidelines—2.2.2) [44]. The deaf person can stop it playing to get more control over the use of sign language video display.

The second aspect is the possibility of increasing the size of videos, so that deaf people can see the facial expressions and gestures of hands better. However, the increase should not mean lowering the quality of the video clip, which commonly occurs where the video is compressed down to a small size, such as 144×176. In this case, it is necessary to compress the video to a format large enough to allow a fairly clear picture, even in the case of a gradual size increase.

The third is the inclusion of subtitles, which are used by deaf and hard-of-hearing to assist their comprehension and the fluency of the sign language interpreter. Providing equivalent alternatives to auditory and visual content is one of the WCAG 2.0 guidelines.

One of the most important aspects of accessibility for deaf people viewing sign language online is the option to slow down the video clip so they can more easily follow individual gestures. This requirement is also reflected in other tools and projects such as Studio SignSmith, which allows the content developer to manually specify the occurrences of pauses, and content-scripting tools from the eSign project, which give similar control over speed, timing and pauses [23]. This enables the adaptation of the video clip to different users with different literacy abilities in sign language. The latest video players, such as Windows Media Player™, MPlayer™ and Adobe Flash™, already provide functionality for control over speed, timing and pauses.

The fifth aspect of accessibility is the possibility of manually moving the video clip around the web site. When the sign language video is displayed over an existing display, it makes sense to add the functionality of moving the clip to another part of the screen when desired by user. This allows the user to simultaneously overview and translates texts and view the sign language video.

The sixth aspect requires the rapid display of video on the web site. Extended waiting time for a video to load may lead to the confusion of the deaf person, since there is no proper feedback on what is going on. Deaf people are especially intolerant to the time lag while playing and require a quick response from the system. It makes sense, therefore, to produce a video that contains markers, so that the video is only loaded once in a set of e-learning materials, and is then switched on by markers when the user moves across web sites. This principle was also used in the ECDL (European Computer Driving Licenses) courses for deaf people [7].

The last aspect is the use of sound. Although the sign language video is aimed at deaf people who do not hear sound, the video can also be used for hard-of-hearing people who wear hearing aids and still know sign language. Research by Debevc [6] has shown that it is appropriate to add sound or a spoken translation in the video clip, together with subtitles, which can be used by hard-of-hearing persons with a hearing aid, who also know sign language. The combination of audio, video and subtitles allows a user to choose which object will receive higher attention.

4.3 Video quality requirements

The criteria for the quality of the video was decided by using the research for measuring the quality for video communication for the deaf and is based on work for standardizing video presentations [13]. Hellström [15] proposes a resolution for the video of CIF format (352*288) and 3:4 aspect ratios to frame the upper body and signing space.

Ensuring good quality of service is also important. The quality for enabling videos requires evaluation of the message media (noise, delays, and jitter) and the clearness and comprehension (intelligibility) of the message. One of the crucial criteria for the quality of a sign language video is the minimal frame rate, which has to be higher than 15 frames per second (fps), as otherwise there will be a significant impact on the transmission and comprehension of sign language [29]. The compression ratio must be optimized such that it allows for good visual detection of hand movements and facial expressions. For the deaf and hard-of-hearing people, it is important that details in motion can be reproduced so that fingers, eyes and mouth are distinguishable even for signs consisting of both hands and arms moving with all the fingers displayed. Blurry fingers in motion (e.g. Hellström) are acceptable, though clearly visibly fingers are preferred.

And finally, acceptable delivery time of the video is an essential point when making the usage comfortable for the deaf and hard-of-hearing. According to Hellström, the picture delay should be less than 1.2 s, which is considered an acceptable delivery time.

A Study from the Cavender project MobileASL [4] regarding using sign language on mobile phones show that the most appropriate encoding is at least 15 fps, but for deaf and hard-of-hearing people even encoding at 10 fps can be used with the difference that, in this case, the facial region must be encoded in better quality than the other regions of the video image. Using eye tracking research [27], it was found to be normal to perceive the facial region at a high visual resolution and the movements of the hands and arms at a lower resolution due to parafoveal vision. Accordingly, it appears that sign language can also be

used for mobile phones together with web applications if the encoder developed within the project MobileASL is used.

5 Transparent video for deaf

5.1 Sign language interpreter module

Our proposed solution for information retrieval is the Sign Language Interpreter Module (SLI Module) [33], which uses a multimodal approach for combining media elements, such as video, audio, subtitles and media navigation controls, into a new layer. Snoek and Worring [35] have extended the definition of multimodality from Nigay and Coutaz [28], and define it as "the capacity of an author of a video document to express a predefined semantic idea, by combining a layout with a specific content, using at least two information channels". Similarly, SLI Module considers three channels/modalities within a video document.

- Visual modality—sign language interpreter.
- Auditory modality—speech.
- Textual modality—subtitles.

In our case, these modalities are manifested as transparent videos, which are exposed over the existing web pages instead of the usual statically positioned videos. With this method, the structure of the web site remains unaltered, and provides a simplified addition to deaf and hard-of-hearing end-users (Fig. 1).

The web site, therefore, combines the video of a sign language interpreter, sound and subtitles over existing, static web sites as a transparent video triggered on the request of the user. After the termination of a short video clip with control options (pause, backward, forward, stop), the original web page is displayed. If necessary, the user only needs to select the appropriate icon or other content-aware element that represents the hyperlink to the sign language video and view the translation. The system is thus simple for authors of web sites, as it is only necessary to add a hyperlink element to play the interpreter video at the appropriate location and connect to the server where the sign language video for the given word, text or other multimedia presentation is located.

During the development stage, the language barriers of deaf and hard-of-hearing users and their bilingualism, characteristics of the major part of this population, have been taken into account. This offers deaf and hard-of-hearing users the translation of a certain word, text, image, photo, animation, video or any other element on the web site. In a nutshell, the SLI Module system offers:

- Enabling of transparent videos over an existing web page without altering its structure.
- Synchronization of video, audio and subtitles.
- On-demand activation by user.
- Presentation of videos anywhere on the web page.
- Control over users' access.

In order to simplify the use of video clips, a central video server that stores sign language video translations is used; these are then used in web applications. In addition to the definitions, even longer video clips can be loaded to the server with detailed explanations of the individual words, concepts or texts, or summarized text for those deaf people who need a simplified explanation. With the proper icon indicating access to the sign language video, the users are pointed to the locations where they can start an

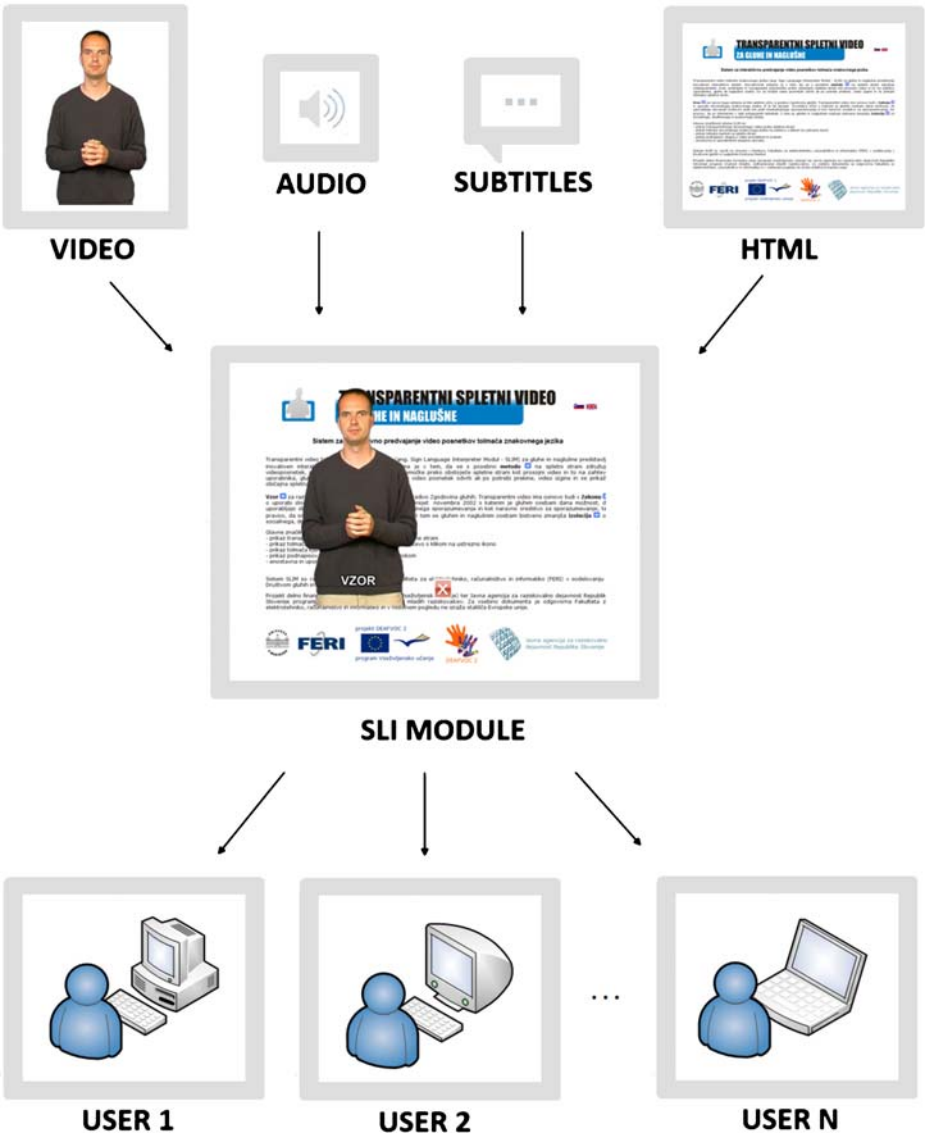

Fig. 1 Modalities of a sign language interpreter module

interpreter video. A video of an interpreter is then played in a transparent frame besides this icon, as an HTML DIV element over the existing web page. Users can hide the video, which is automatically ended, by clicking the x-sign, which is widely known symbol for the cancellation of the operation.

5.2 Creating transparent sign language video

The quality of transparent video required for deaf and hard-of-hearing users can be developed only on the basis of high quality, pure, basic DV video, since these users require

clean video in order to focus on the details, such as finger movements for the sign language and the lip movements for lip-reading. Video is recorded with a person standing in front of a green background, also known as a chroma key background. It is clear that the person should not be wearing anything of the same colour as the background. This provides the necessary contrast between the standing person and the background, and enables the removal of the background with video modeling software. The result appears as a video with a so-called transparent (non-opaque) background.

The video recorded on the computer must be uncompressed and in its original size. For the multimedia container format in our project, we have used uncompressed Audio Video Interleave (AVI), with a resolution of 750×567, 25 frames per second, with 48 kHz audio and 32 bit sampling. The video was then imported into the software, where the Colour Key effect was used to remove the green background and soften the edges between the object and the background. This procedure and the use of the Shockwave Flash (SWF) format has resulted in the high quality of the video, presenting the moves of the interpreter clearly enough for the users to see the facial mimicry and to focus on the fingers without a blurry image.

Figure 2 presents an example the conversion of the image into a transparent form. The first image represents the original image with a green background; the second shows a transparent image that has the background removed. The removed background on the image is shown as a black background. The third image shows us the softening of the edges of the body so that the person in the picture fits to the background of the web page better.

The original video was first exported into a transparent Flash video with a resolution of 240×320 (QVGA format), with a frame rate of 25 fps and a sampling of 700 kilobits per second. Such a Flash video is suitable for conversion to Shockwave Flash (SWF) format, which was designed to deliver vector graphics and animation over the Internet.

With this procedure, we have achieved video details with sufficiently strong sign language interpreter movement, so that users can see facial expressions and fingers without blurriness.

5.3 Integration process

As already mentioned, one of the key problems in the construction of web sites for people with disabilities is the implementation of accessibility features.

Two of the ways in which the implementation process is possible include the designing of a new web site, similar to the existing non-accessible web site, with added accessibility features, or an upgrade of the existing web site.

a) original image b) image with removed background c) edge sharpening

Fig. 2 Edge sharpening procedure

Designing a parallel web site in another language is often a time-consuming job; therefore an upgrade is more suitable. The integration is the crucial step. Consequently, the integration of new code into the web pages must be as simple as possible.

In planning the SLI Module integration into existing web sites, we considered the ease of implementation. By integrating HTML and JavaScript code, we were able to achieve the following conditions.

– Cross-browser compatibility (Microsoft Internet Explorer and Mozilla Firefox).
– Viewing several transparent video layers on the existing web page.

The inclusion of modalities is illustrated in Fig. 3. Video production is done separately in the background of the entire process, while its output presents transparent Flash videos. Video linkage and activation events are integrated into the existing web page with HTML and are performed with the help of JavaScript code blocks.

All implementation of the video layer is carried out when the user clicks on the icon to view the video. An example of the activation icon is shown in Fig. 4. From the end-user's perspective, the additional element is the activation icon, which is an image button. The dimensions of the icon in our system are 15×15 pixels and can be inserted into the text between lines of paragraph without altering the text. This feature is a notable distinction in comparison to current solutions on the market, which use a larger size of statically integrated sign language videos (240×320 pixels at least).

6 Evaluation

6.1 Goal of testing

During the test of our system, we obtained feedback from end users (deaf and hard-of-hearing) on user experience satisfaction [19]. Since this is an incremental prototype, we did

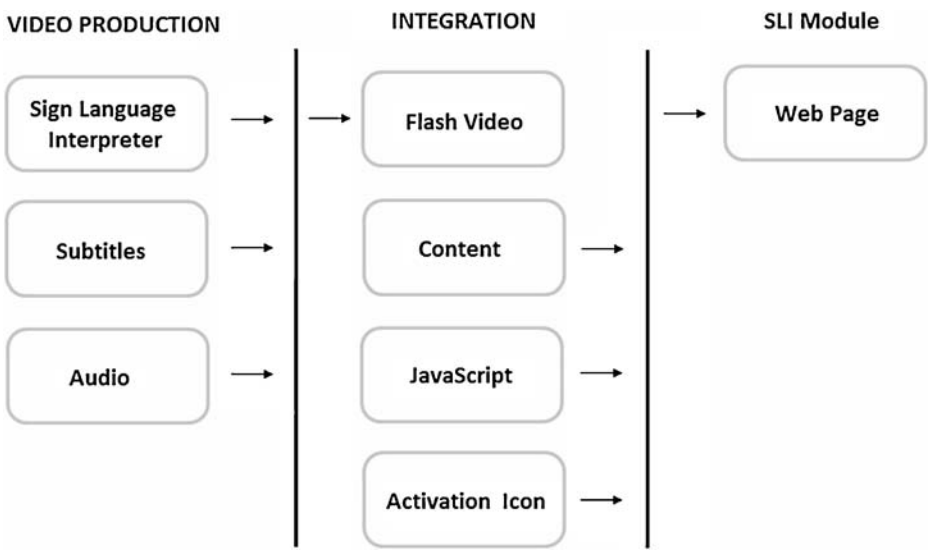

Fig. 3 Inclusion of the modalities into existing web pages

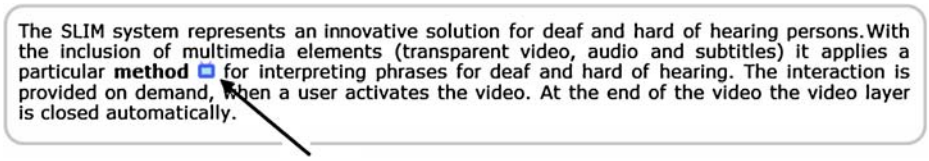

Fig. 4 Image button for activating the transparent sign language video

not want to test the effectiveness of the browser application, such as the capture of quantitative data (for example, the number of errors made). We used a questionnaire to verify the general impression of the usefulness of the system. In order to gain maximal insight, such indirect usability tests as questionnaires must be supplemented with direct usability tests, e.g. thinking aloud or observation [30]. Since standard thinking aloud was not applicable, we applied the Gestural Talk Aloud Method (see Section 6.3).

6.2 Experimental setting

N=18 deaf people between the ages of 17 and 51 whose first language is sign language participated in the evaluation of the usefulness of a transparent video model. Participants were testing a prototype web site which contained four video icons to launch sign language videos. The sign language videos integrated the general use of the x-button for closing / ending video playback.

6.3 Methodology

The data in both experiments was collected through the Gestural Talk Aloud Protocol [30] with a simultaneous translation of speech and sign language, a short questionnaire consisting of four questions with four closed questions and a group discussion.

6.4 Procedure

The entire procedure lasted approximately 1 h and was conducted in the order presented in Table 1. Before the users began to work, they received a brief overview presentation of the entire evaluation. First, we asked them to start the web browser (Microsoft Internet Explorer or Mozilla Firefox) and to connect to the URL of the system. Then we asked the users to read the text and activate the interactive video icon as soon as they noticed it in the text. In our case, the icon was an image of TV. To eliminate prior Internet skills, participants were first presented with a sketch of the visual appearance of the icons. They could watch the video, according to their needs, within a 20-minute time frame.

At the end of the test, the participants completed a short questionnaire containing 4 questions with yes / no answers. A group debate on the advantages and disadvantages of the system and their general impression of a sign language video followed at the end. This group debate lasted about 30 min.

7 Results and discussion

Based on the results from the questionnaire, all users in the evaluation study showed a positive attitude towards the video; the first question was answered with yes by all users

Table 1 Evaluation procedure

Activity	Time
1. Introduction of the evaluation study	5 min
2. Tasks:	20 min
2.1 Open a browser	
2.2 Go to URL of the system	
2.3 Read the text and find the interactive icon	
2.4 Activate the interactive icon and watch the video	
3. Fill out the questionnaire	5 min
4. Participate in a group discussion	30 min

(Table 2). Most of the users (88%) would prefer to have transparent video on all pages, while 12% of participants did not show an interest in having video available. The video resolution in our experiment was 450×550 pixels, which was sufficient for 67% of the users, while 33% of the participants found the video oversized. This confirmed the necessity of having a user-controlled video resizing function. The appearance of the interactive video icon in the shape of TV symbol was well accepted by 83% of the users.

These results and experiences gathered through the evaluation show that the transparent sign language video idea is appropriate for the users and this satisfies the defined accessibility requirements.

The evaluation findings revealed that deaf and hard-of-hearing users appreciate transparent sign language video and would want to use it in the future. The results also confirm that the transparent video would be an appropriate added value to existent web sites. We have to stress that the goal of our study was primarily to obtain valuable information about our prototypes from the aspect of satisfaction and not to test the common task-oriented parameters when testing browsers, such as effectiveness and efficiency or to statistically compare our prototype with other approaches (e.g., videos on a separate window, or videos statically integrated in the layout), which will be done in future work.

8 Conclusion

According to previous research there is an urgent need to improve the accessibility of web sites, especially for deaf and hard-of-hearing persons who are, unfortunately, fundamentally deprived of translations in sign language, their first language. Although standards such as WCAG 2.0 cover the needs of deaf and hard-of-hearing people, they are those standards more or less adapted for appropriate presentation of information in written form, and are not

Table 2 Questionnaire results

Questions	Yes	No
1. Did you like the video?	18 (100%)	–
2. Would you prefer video to be present on all the Web pages?	16 (88%)	2 (12%)
3. Was the video size too large?	6 (33%)	12 (67%)
4. Did you like the interactive icon used?	15 (83%)	3 (17%)

sufficient for the vast majority of the deaf and hard-of-hearing for whom it is necessary to have information presented in the form of a sign language video.

In developing the SLI Module for the presentation of sign language videos with a help of web layers, the basic requirements necessary for the deaf and hard-of-hearing users to use the video were taken into account, such as: appropriate video size; quality of service; the accessibility and linguistic characteristics of the deaf and hard-of-hearing and bilingualism, all characteristics of a substantial part of this population. The SLI Module offers the possibility of prioritizing sign language and emphasizing the importance of acquiring knowledge and delivering information in that language. This offers deaf and hard-of-hearing people whose first language is sign language the translation of specific words, text, images, photos, animation or video clips which can be found on the web.

The SLI Module is primarily intended for deaf and hard-of-hearing people, so it adjusts to their needs on a contextual and technical basis. The novelty of this system is evident from the fact that the screen of the web site combines video, audio, subtitles and navigation options over the existing web page, which usually contains a lot of text and static positioning (for example, e-material, governmental web pages), as a transparent video at the request of the user.

Results of the evaluation show that deaf users appreciated the SLI Module and had a great desire to use this form of sign language presentation to visit other web sites. In the long run, the SLI Module offers easy and fast integration of sign language video into existing web pages without much effort. For the system to function, the JavaScript implementation code for retrieving and presenting the sign language video must be included, and the interactive icons positioned into the appropriate locations on the web page.

Using the sign language video in the materials also increases the daily exposure to sign language and thereby enables deaf and hard-of-hearing people to use the material in a working and social environment as well as in education, as they can more easily repeat the difficult parts and learn to be independent. It is expected to increase the literacy of another language, namely the mother tongue, of deaf people by providing more materials in their sign language. It would be easier for them to merge into the common social formation, while maintaining their own identity, improve their self-esteem and developing their culture and language.

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