Disability-Friendly Website Design

Consequences for Nonimpaired Users and Users with Impairments

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"The power of the web is in its universality. Access by everyone—regardless of disability—is an essential aspect." (Tim Berner Lee, the founder of the world wide web, n.d.)

Thank you
...Jürgen Sauer, Andreas S., Alain und Jürgen B, Access for All, Andreas Ue., Patrick, Ivana, Jan, Mom, Dad and all the other supporters I did not mention here.

Note with regard to accessibility:
Please note that this PDF was created with the aim of being accessible to users with impairments. The file was created on an apple computer with MS Word and Adobe Acrobat. The accessibility with screenreading software was tested by using the apple voice over application. Because of the necessity to report many statistical results and measures, some of the tables may not be userfriendly via screenreading software. We applogize for that. However, please not that all the information provided in the tables is discussed and summarized in the main text. Furthermore, it is to note that although the file was tested with the voice over application, there may happen difficulties with regard to accessibility when using other screenreading software.

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1. Introduction

The world wide web (web) is indispensable for the modern society. Many people have to use websites on a daily basis to get the information they need, be it at work, at school or at home. Being able to use websites is thus a prerequisite for members of such a society. Even though having access to information on the web is essential these days, people with physical or cognitive impairments often face barriers when using websites (e.g., Al-Wabil, Zaphiris, & Wilson, 2007; Chiang, Cole, Gupta, Kaiser, & Starren, 2005; Disability Rights Commission, 2004; Ruth-Janneck, 2011). Barriers occur because a large number of websites do not sufficiently consider needs of users with impairments (e.g., Gonçalves, Martins, Pereira, Oliveira, & Ferreira, 2013; Nurmela, Pirhonen, & Salminen, 2013). Such needs are, for instance, a high contrast between text and background for users with visual impairments, text alternatives describing audio content for users with hearing impairments and easy-to-read texts for people with cognitive impairments (e.g., Thatcher et al., 2006). There are different reasons why practitioners do not consider needs of people with impairments, including a lack of awareness (e.g., they do not know about specific needs of people with impairments) and economic considerations (e.g., they assume considering such needs increases work effort). A further prevalent and important reason for not considering needs of people with impairments are negative preconceptions about disability-friendly website design (e.g., practitioners assume considering needs of people with impairments results in ugly, boring and dull websites, which is disadvantageous for nonimpaired users; Ellcessor, 2014; Farrelly, 2011; Lazar, Dudley-Sponaugle, & Greenidge, 2004; Thatcher et al., 2006). The present work concerns such negative preconceptions by investigating possible side effects for nonimpaired users when applying disability-friendly website design.

2. Background

2.1 Disability

The World Health Organisation (WHO) estimates that to date about 15% of the population has some kind of disability. Disability is a multidimensional concept comprising different factors that influence the level of human functioning in specified situations (WHO, 2011). A well-accepted model that illustrates these factors is the International Classification of Functioning, Disability, and Health (ICF) (e.g., Bickenbach, Chatterji, Badley, & Üstün, 1999; WHO, 2001; 2011). Figure 1 provides an overview of this model. The ICF suggests a bio-psycho-social perspective, stating that there are three main factors influencing disability: (a) health condition, (b) personal factors, and (c) environmental factors. Health condition denotes diseases, disorders or injuries, such as damage to an optic nerve and multiple sclerosis. Personal factors constitute internal resources, such as motivation and self-esteem. Environmental factors imply the context in which, or with which, a person is acting, such as built environment, products, and technology. These three interacting main factors determine disability reflected in problems in human functioning. The ICF distinguishes three categories of problems in human functioning: (d) impairments, (e) activity limitations and (f) participation restrictions. Impairments are defined as problems in body functioning, such as blindness or deafness. Activity limitations imply difficulties in executing activities, such as riding a bicycle or using a website. Participation restrictions denote problems with participation in any area of life, such as encountering discrimination in education or employment. In sum, disability signifies "the negative aspects of the interaction between an individual (with a health condition) and that individual's contextual factors (environmental and personal factors)" (WHO, 2011, p. 4).

This bio-psycho-social perspective of disability implies that contextual factors may not only cause barriers in human functioning but can also act as facilitators to improve participation. While a flight of stairs is a major barrier for a wheelchair user, a ramp enables the same person to enter a building. The present work is pursuing this idea of creating supportive environmental conditions to improve human functioning and accessibility for people with disabilities.

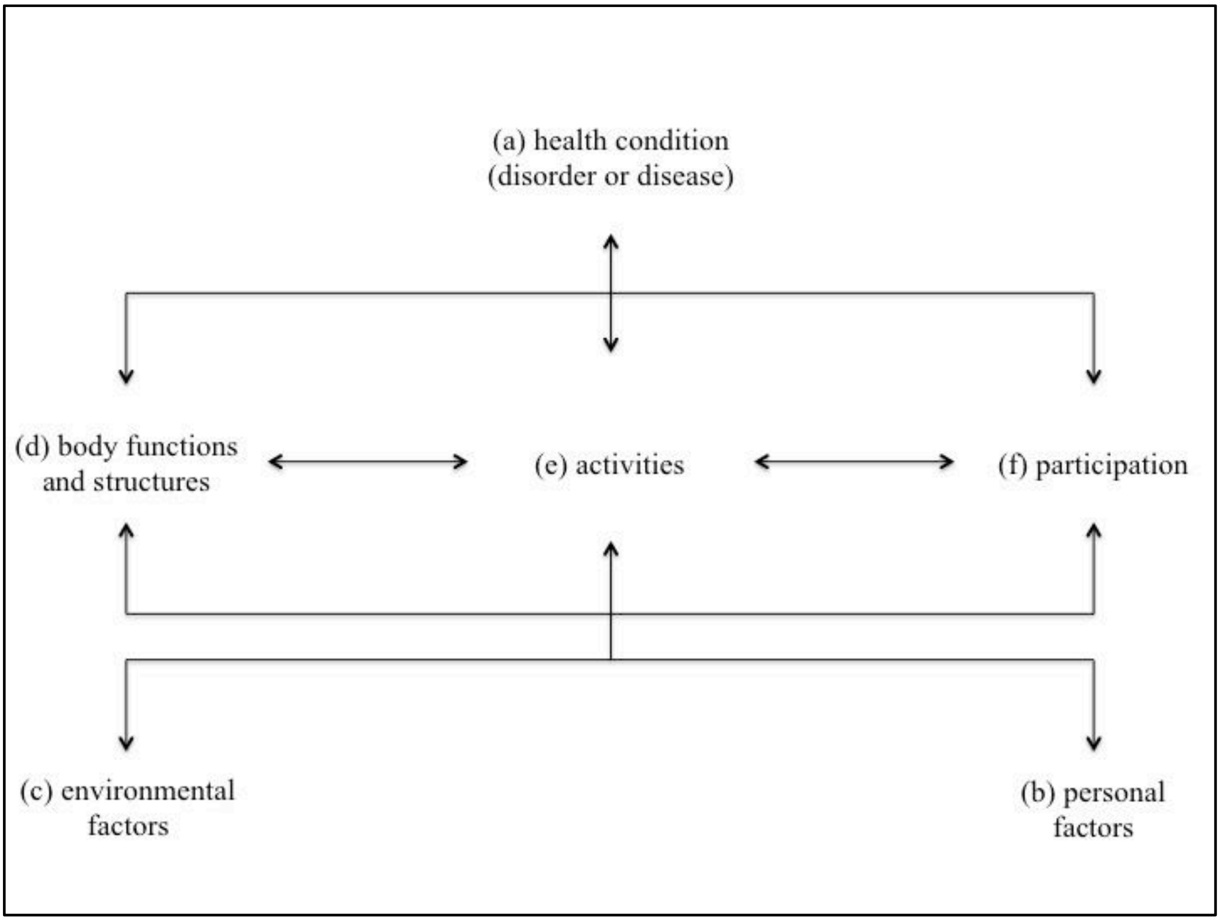

Figure 1. A model of disability adapted from the international classification of functioning, disability and health (WHO, 2001)

2.2 Accessibility

The concept of 'accessibility' implies a person-environment relationship like the concept of disability but with a different perspective (Iwarsson & Ståhl, 2003). While the term disability focuses on possible barriers that people encounter, accessibility emphasises the overcoming of such barriers by creating environments that foster participation and inclusion (WHO, 2011). In this case, 'environment' signifies various contextual factors in different domains, such as buildings, roads, public transport, and technology. Accordingly, the international standard 9241-171 'guidance on software accessibility' defines accessibility as "the usability of a product, service, environment or facility by people with the widest range of capabilities" (International Organisation for Standardisation [ISO], 2008, p. 2). Since accessibility can be applied in different domains, the specific aim of accessibility can vary as well, be it having access to physical environments, social activities, services or information

(Iwarsson & Ståhl, 2003). Out of all these domains and aims, the present work focuses on the accessibility of technology and information, particularly on the accessibility of websites (hereafter "web accessibility").

2.3 Web Accessibility

Web accessibility aims at enabling access to information on websites (e.g., Henry, 2006). Enabling access to such information is particularly important for people with impairments. This is because limited physical or cognitive functioning may cause severe problems when using websites (e.g., Cunningham, 2012; Ruth-Janneck, 2011; Thatcher et al., 2006; Vu & Proctor, 2011). There are four major categories of impairments that are related to problems in using websites: (a) Visual impairments, (b) hearing impairments, (c) cognitive impairments, and (d) motor impairments (e.g., Thatcher et al., 2006; Vu & Proctor, 2011). These kinds of impairments concern in sum about 10% of the population (Kraus, 2017; data of the United States of America). Table 1 provides the prevalences of each impairment category and related problems in using websites.

Table 1. Examples of problems in using websites for people with impairments (see Thatcher et al., 2006 for further examples)

Impairment	Prevalences	Example 1	Example 2
Visual impairments	2.3%	Visual information (e.g., images or text) cannot be seen.	Text cannot be read because the font is small.
Hearing impairments	3.6%	Audio information (e.g., in a video or sound) cannot be heard.	Problems with understanding written text because deaf people are often users with low literacy.
Cognitive impairments	4.8%	Problems in finding specific information because the layout of the website is complex (e.g., many pages that are not organized consistently).	Problems with navigating the website because the navigation is not clearly distinguished from other parts of the website.
Motor impairments	?	Problems with clicking on small items because of tremor.	Problems with navigating a website because one cannot use a mouse.

Note. The prevalences are based on data of the USA reported in Kraus (2017). Since reports on motor impairments usually comprise leg and arm impairments, a statement about the prevalence of motor impairments limiting the use of websites is difficult.

Generally, web accessibility is an approach to reduce and overcome problems, like they are presented in table 1 (e.g., Cunningham, 2012; Henry, 2006; Ruth-Janneck, 2011). However, the exact meaning of the term web accessibility is inconsistently defined in the literature (Yesilada, Brajnik, Vigo, & Harper, 2012). Table 2 provides an inexhaustive list of such definitions (see Petrie, Savva, & Power, 2015 for a review of definitions).

Table 2. Overview of definitions of web accessibility

Number	Definitions
1	Web accessibility means that people with disabilities can use the web. More specifically, web accessibility means that people with disabilities can perceive, understand, navigate, and interact with the web, and that they can contribute to the web (Henry, 2006, p. 2).
2	The extent to which a website can be used by users with specified disabilities to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (British Standard Institute, 2010, p. 3).
3	Designing human-system [including websites] interactions to increase accessibility promotes increased effectiveness, efficiency, and satisfaction for people having a wide variety of capabilities and preferences. Accessibility is therefore strongly related to the concept of usability (ISO 9241-171, 2008).
4	Technology [a website] is accessible if it can be used as effectively by people with disabilities as by those without (Thatcher, 2011).
5	A website is accessible if it is effective, efficient and satisfactory for more people in more situations (Thatcher et al., 2003, p. 8).
6	... individuals with disabilities can access and use them [websites] as effectively as people who don't have disabilities. (Slatin & Rush, 2003, p. 3)
7	An accessible website is a website that can be successfully used by people with various disabilities. People with different disabilities may be using different forms of assistive technology, such as screen readers, alternative keyboards, or alternative pointing devices. A website that is accessible is flexible enough to work with these various assistive technology devices (Lazar et al., 2003, p. 990).
8	Web accessibility is the concept of making sure that websites can work properly for users with disabilities that are using alternative input or output devices, such as screen readers or adaptive keyboards (Lazar et al., 2011, p. 108).
9	Web accessibility is the inclusive practice of making websites usable by people of all abilities and disabilities. (Chevalier, Dommes, & Martins, 2013, p. 1012)
10	All people, particularly disabled and older people, can use websites in a range of contexts of use, including mainstream and assistive technologies; to achieve this, websites need to be designed and developed to support usability across these contexts (Petrie et al., 2015, p. 3)

Table 2 shows that there are considerable differences between the various definitions. These differences are for instance, whether only people with impairments are considered (e.g., definitions 1 and 2 in table 2) or users without impairments as well (e.g., definitions 4 and 6 in table 2). Further differences concern the goals of web accessibility. Some of the definitions only mention effectiveness-related goals, such as "...can be used as effectively…" (e.g., definitions 4 and 6 in table 2). Other definitions mention further goals, such as efficiency and satisfaction (e.g., definitions 2 and 3 in table 2). Effectiveness stands for the accuracy and completeness with which someone can achieve goals (e.g., "can be used", "can access") (ISO 9241-11, 1998). Efficiency represents the effort required to achieve a goal (ISO 9241-11, 1998) and user satisfaction can be described as the "users' comfort with and positive attitudes towards the use of the system" (e.g., Frøkjær, Hertzum, & Hornbæk, 2000, p. 345). Additionally to the user groups and the goals, the definitions differ concerning the focus on assistive tools. Assistive tools are hardware or software tools that support users with impairments. Such tools include screen reading software, which reads out loud the content on a website for users with impaired eyesight; and alternative keyboards, which provide specific buttons or joysticks, for users with motor impairments (see Thatcher et al., 2006 for further examples). While some of the definitions in table 2 mention assistive tools as crucial aspect of web accessibility (e.g., definitions 7 and 8 in table 2), other definitions do not even mention assistive tools (e.g., definitions 1 and 2 in table 2). These differences among definitions and the exact meaning of web accessibility is still a matter of debate in the literature (e.g., Petrie et al., 2015; Petrie & Bevan, 2009; Petrie & Kheir, 2007; Yesilada et al., 2012). However, of all these definitions, definition 1 (see table 2) seems to be the most common one. Authors in the field of web accessibility frequently refer to this definition (e.g., Badge, Dawson, Cann, & Scott, 2008; Faias, Ferreira, & Leite, 2007; Henry, 2006; Ismailova & Inal, 2017; Pinto, Sales, Doucet, Fernández-Ramos, & Guerrero, 2007; Porta & Ravarelli, 2012; Quirk & Conway, 2011; Thatcher et al., 2006). Furthermore, in a survey, 300 people interested in web accessibility preferred definition 1 (see table 2) compared to a number of other definitions (Yesilada et al., 2012). This is not surprising because definition 1 (see table 2) has been proposed by the world wide web Consortium (W3C; see www.w3c.org) and its web Accessibility Initiative (WAI; see www.w3.org/WAI/). The W3C is the leading international organisation for standards concerning the web. The WAI is a specific initiative of the W3C, which comprises different working groups that focus on the accessibility of the web for people with impairments. Since definition 1 (see table 2) is well-accepted among researchers and practitioners, and constitutes the prevailing opinion, the present thesis applies definition 1 (see table 2) for the characterisation of the term web accessibility.

Following this definition, it is to consider that whether people with impairments can perceive, understand, navigate, and interact with websites depends on different components. A common model of web accessibility provides an overview of such components (Chisholm & Henry, 2005). Figure 2 shows this model and its main components, which are: (a) the user, (b) assistive tools, (c) the developers, (d) web accessibility guidelines, and (e) the website design. These components are interdependent and determine together the level of web accessibility. (a) The users can affect the level of web accessibility with their characteristics. This includes the type and severity of impairment (e.g., partially sighted or blind) and the skills to use websites (i.e., a highly skilled user may cope with more issues). (b) As mentioned above, assistive tools are supportive soft- or hardware tools that aid website users with impairments. The availability or unavailability of such assistive tools may influence the level of web accessibility. (c) Developers influence the level of web accessibility because they create websites. Awareness of, and knowledge about web accessibility increase the chance that developers consider web accessibility issues when creating websites (Farrelly, 2011). (d) Web accessibility guidelines are an important tool for practitioners to create accessible websites. Such guidelines comprise various design recommendations that support users with different kinds of disabilities (e.g., Caldwell, Cooper, Reid, & Vanderheiden, 2008; United States Access Board, 2000). To (or not to) apply accessibility guidelines, and the usefulness of their recommendations influences the level of web accessibility. (e) Finally, the website itself can comprise many or few disability-friendly characteristics that are meant to support users with different kinds of impairments (e.g., high contrast between text and background, clear navigation structure, operability with the screen reading software, operability via keyboard, and low text complexity, see Caldwell et al., 2008 for more examples). Comprising many such characteristics would result in a disability-friendly website design.

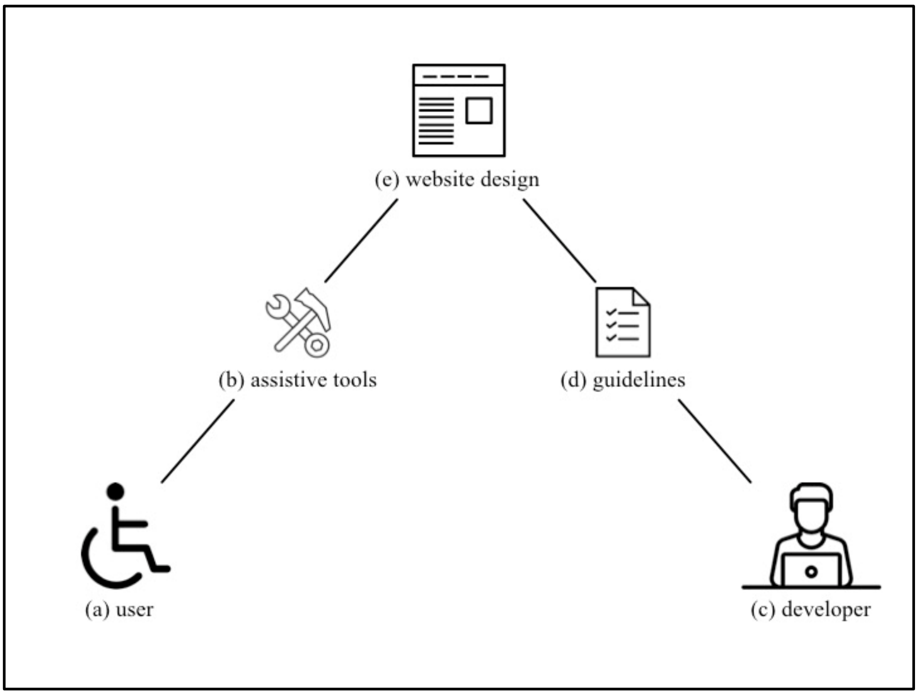

Figure 2. Adapted from the model of web accessibility components (Chisholm & Henry, 2005)

Although all components in figure 2 are important to increase web accessibility, the present thesis mainly focuses on the two components (d) guidelines and (e) website design. While the website design concerns the inherent characteristics of a website, web accessibility guidelines are tools that may help practitioners to create disability-friendly website characteristics, which are meant to support users with impairments.

There are several web accessibility guidelines available, which are fairly similar (e.g., Caldwell et al., 2008; United States Access Board, 2000; IBM, 2017). Such web accessibility guidelines aim to recommend various website characteristics (see table 3 for examples of such recommendations) that are meant to support people with various types of impairments. The guidelines thus function as a general standard, which practitioners can use as a kind of a checklist in the process of creating websites. This should guarantee that their design considers the typical needs of people with impairments (e.g., Connor, 2012; Cunningham, 2012; Thatcher et al., 2006).

Table 3. Examples of recommendations provided by web accessibility guidelines (examples from Caldwell et al., 2008)

Number	Example
1	All non-text content that is presented to the user has a text alternative that serves the equivalent purpose.
2	Color is not used as the only visual means of conveying information, indicating an action, prompting a response, or distinguishing a visual element.
3	The visual presentation of text and images of text has a contrast ratio of at least 4.5:1.
4	All functionality of the content is operable through a keyboard interface without requiring specific timings for individual keystrokes, except where the underlying function requires input that depends on the path of the user's movement and not just the endpoints.
5	Navigational mechanisms that are repeated on multiple web pages within a set of web pages occur in the same relative order each time they are repeated unless a change is initiated by the user.

The term "disability-friendly website design" refers to conformance with web accessibility guidelines. High conformance with guidelines (i.e., a website complies with many recommendations of guidelines) would imply a high level of disability-friendly website design, whereas low conformance with guidelines would imply a low level of disability-friendly website design. Such an understanding of disability-friendly website design further implies that it is not a binary concept, which would mean that a website is either disability-friendly or not, but rather a continuous concept, which means that a website can be more or less disability-friendly (i.e., be more or less in accordance with web accessibility guidelines; Sullivan & Matson, 2000). The approach of applying guidelines to consider disability-friendly design is currently the common procedure in practice (e.g., Connor, 2012; Cunningham, 2012; Henry, 2005; Power, Freire, Petrie, & Swallow, 2012; Thatcher et al., 2006) and also recommended by the international standard organisation (ISO 40500, 2012). It is to consider that in the literature, authors usually equate a website's conformance with guidelines to the level of "web accessibility" (e.g., Huber & Vitouch, 2008; Petrie & Kheir, 2007). Consequently, many authors write about 'high or low web accessibility' when they refer to the accordance with web accessibility guidelines, which would imply that web accessibility is a website inherent concept. However, the present work understands the term web accessibility not simply as a website inherent quality but as a context- and person-dependent construct that comprises more components than only the website characteristics and its conformance to accessibility guidelines (see figure 2). Therefore, when considering the website inherent perspective focusing solely on the website characteristics and its compliance to web accessibility guidelines, the present work will hereafter refer to the term "disability-friendly website design" (being equal to a website's conformance with web accessibility guidelines). Although the term disability-friendly website design is rather uncommon in the literature, it is used in the present work to clearly distinguish the whole multi-component construct "web accessibility" (see figure 2) from the website inherent perspective, which focuses solely on the website characteristics and its compliance with accessibility guidelines (see figure 2, e & d).

To focus on website characteristics and their compliance with accessibility guidelines seems to be of particular importance to advance the field of web accessibility because research has shown that most websites (i.e., 90% or more) do not (or only to a limited extent) consider recommendations of guidelines and disability-friendly design characteristics (Bolfing et al., 2016; Gonçalves et al., 2013; Nurmela et al., 2013). Only websites that are legally required to apply disability-friendly website design (e.g., some federal authorities and governmental sectors) show slightly better ratios. Reasons for the low levels of disability-friendly design in websites include practitioners' lack of knowledge and awareness concerning web accessibility and the assumption that implementing disability-friendly website design results in high costs (Farrelly, 2011). A further reason is the assumption of practitioners that disability-friendly website design may have negative consequences for nonimpaired users (e.g., nonimpaired users perceive disability-friendly website design as ugly and not user-friendly). The latter reason is of particular importance because such negative assumptions are very common among practitioners and thus a major impediment for disability-friendly website design (Connor, 2012; Ellcessor, 2014; Petrie, Hamilton, & King, 2004; Thatcher et al., 2006).

Therefore, the present work focuses on this issue by addressing effects of disability-friendly website design on nonimpaired users.

2.4 Disability-Friendly Website Design and Nonimpaired Users

Researchers and practitioners in the field emphasise the importance of possible consequences of disability-friendly website design for nonimpaired users for several reasons (e.g., Huber & Vitouch, 2008; Petrie et al., 2004; Petrie & Kheir, 2007; Thatcher et al., 2006; Yesilada, Brajnik, & Harper, 2011; Yesilada, Brajnik, Vigo, & Harper, 2013). First, although disability-friendly website design is meant to support users with impairments, it is to assume that applying specific design characteristics affects the content (e.g., colour, text, structure, etc.) and thus all the users who use the website. This apparently includes people without impairments. Since the vast majority of users are usually nonimpaired, possible effects on these users are particularly important for practitioners. Empirical findings about the consequences of disability-friendly website design for nonimpaired users may thus help practitioners to decide whether such design characteristics should be implemented in websites or not. Second, applying disability-friendly website design is causing a certain amount of costs and work effort (e.g., Connor, 2012; Farrelly, 2011). Knowledge about the effects of disability-friendly website design on nonimpaired users might help practitioners with their cost-benefits considerations because they might better estimate the consequences. Third, many practitioners hold negative beliefs about disability-friendly website design, such as disability-friendly characteristics make websites ugly, boring or not user-friendly for nonimpaired users (e.g., Connor, 2012; Ellcessor, 2014; Petrie et al., 2004; Thatcher et al., 2006). Such negative assumptions are very common among practitioners and may hinder the implementation of disability-friendly design because nonimpaired users are the important target group in most cases (Farrelly, 2011). Although such beliefs are common, there is no empirical evidence supporting these negative assumptions. Investigating consequences of disability-friendly website design for nonimpaired users would thus clarify whether the negative assumptions are justified or not. If results would show benefits of disability-friendly website design for nonimpaired users, practitioners might even be encouraged to apply disability-friendly website design. This is because in such a case, applying disability-friendly website design would benefit a wide range of users including users with and without impairments, which would be profitable for practitioners. Despite the importance of such knowledge, there is surprisingly little empirical research that has investigated effects of disability-friendly website design on nonimpaired users.

One of the first studies that empirically related disability-friendly website design to nonimpaired users compared six websites containing different content (Disability Rights Commission, 2004). Three websites were considered to be highly disability-friendly (i.e., high compliance to web accessibility guidelines), while three other websites complied with a very low level of disability-friendly website design (i.e., low conformance with web accessibility guidelines). Users with and without impairments used these websites and solved tasks on them (e.g., searched for a specific piece of information). The results indicated that disability-friendly website design benefits both, users with and without impairments concerning task completion rate, but only users with impairments concerning task completion time. A further study discussed effects of disability-friendly website design on nonimpaired users with a focus on aesthetics (Petrie et al., 2004). The authors evaluated 100 websites with different levels of disability-friendly website design concerning aesthetical characteristics. The study concluded that some aspects of disability-friendly website design may interfere with design characteristics that are important for nonimpaired users (e.g., color contrast and visual structure of the website). Another study applied a more technical approach by showing that a website's higher conformance to web accessibility guidelines is associated with higher scores in an automated usability test, which is an automated test focusing on user-friendly design characteristics for nonimpaired users (Sullivan & Matson, 2000). A later study employed user testing, in which blind and nonimpaired users used similar websites and reported occurring problems (Petrie & Kheir, 2007). The mentioned problems were compared afterwards, which resulted in an overlap of problems of about 15%. This is a substantial amount of overlap, considering that blind users browse a website totally differently compared to nonimpaired users (e.g., navigating the website with keyboard and using assistive tools like a screen reader). This overlap of problems indicates that people with and without impairments may have -to a certain extent- similar needs. In accordance with this assumption, a further study showed that a website's compliance with web accessibility guidelines is associated with higher ratings of nonimpaired users in perceived usability (Huber & Vitouch, 2008). However, another study did not find any association between the conformance of a website with accessibility guidelines and subjective usability ratings of participants (Arrue, Fajardo, Lopez, & Vigo, 2007). The most recent study dealing with disability-friendly website design and nonimpaired users compared two different websites with different levels of disability-friendly website design (Pascual, Ribera, Granollers, & Coiduras, 2014). Nonimpaired users and users with visual impairments used these websites, while performance and subjective rating measures were taken. The results showed that visually impaired users benefitted from disability-friendly website design in terms of task completion rate and time, whereas there was no difference between the website with higher and lower levels of disability-friendly design for nonimpaired users.

The current state of research provides inconsistent results concerning the effects of disability-friendly website design on nonimpaired users. While some studies showed beneficial effects of disability-friendly website design for nonimpaired users, other work could not show such effects. In addition to the inconsistent findings, some methodological issues have to be considered concerning the studies described. First, many of these studies compared websites containing different content (e.g., government, e-finance, entertainment, and leisure), which were also different concerning the level of disability-friendly website design. Such a comparison of different websites comprising different content may distort results because other aspects than disability-friendly design characteristics may influence users when testing the websites. For example, a website of a bank is usually very different from a website of a restaurant. The content (e.g., text and images) may differ significantly, which might influence the results but is not specifically related to disability-friendly website design. Therefore, future research should control for such confounding variables by using websites with the same content but different levels of disability-friendly website design. Second, previous studies tested very few nonimpaired participants, such as Pascual et al. (2014) who tested four nonimpaired users or Petrie & Kheir (2007) who tested six participants without impairments. Because of these low numbers of participants, valid inferential statistical conclusions were not possible. Research examining effects of disability-friendly website design on nonimpaired users with larger samples is thus needed. Third, most of the described studies focused on performance (i.e., task completion rate and time) or subjective ratings of the ease of use of the website. To have a more comprehensive picture about the consequences of disability-friendly website design for nonimpaired users, studies should investigate a wider range of outcome measures (e.g., perceived workload, aesthetics, and affect). According to the outlined research gaps and the methodological issues of previous studies, the present work aims to investigate the consequences of disability-friendly website design on nonimpaired users under consideration of these concerns.

3. The Present Work

The present work comprises four empirical studies, focusing mainly on effects of disability-friendly website design on nonimpaired users. These studies built on each other and are hereinafter summarised, followed by the four papers in full-text (see sections 3.5 – 3.8). Table 4 provides an overview of the four studies including their specific research questions, variables of interest, methodological procedures and main findings.

3.1 Summary of Study One

The first study aimed to develop a valid manipulation of disability-friendly website design according to pertinent web accessibility guidelines (i.e., web content accessibility guidelines 2.0 [WCAG 2.0], Caldwell et al., 2008). To contribute to previous work, we aimed to minimise possible confounding factors, as described in section 2.4. Therefore, we did not use different websites with different levels of disability-friendly design but created a manipulation by using different versions of a single website. These versions differed with regard to the level of disability-friendly design (i.e., compliance with web accessibility guidelines) but contained the same main content (i.e., a website of a city in Liechtenstein). With this approach text and images on the website were standardised and the only things manipulated on the website were the recommendations of the accessibility guidelines. Furthermore, the developed manipulation should be used to investigate effects of disability-friendly website design on a wide range of outcome measures including performance and subjective ratings to expand the pool of investigated outcome measures. Since the main goal of the first study was to develop and test the websites, we deliberately chose a sample of nonimpaired students, which was comparably easy to recruit. The results of the first study showed beneficial effects of disability-friendly website design for nonimpaired users (e.g., task completion time, task completion rate, perceived aesthetics and perceived workload). This lead to the conclusion that negative assumptions of practitioners may not be empirically supported. Furthermore, since study one showed clear benefits of disability-friendly website design for nonimpaired users, it raised the question of how effects of disability-friendly website design differ between nonimpaired users and users with impairments. To deal with this question we conducted study two.

3.2 Summary of Study Two

In study two, we were interested in how the effects of disability-friendly website design differ between nonimpaired users and users with impairments. Clarifying such differences would provide more comprehensive information for practitioners concerning the consequences of disability-friendly website design. Such information could be helpful for practitioners when they decide whether accessibility guidelines should be implemented or not. Therefore, the main goal of the second study was to recruit two matched samples, one with people who are not impaired and one with people who are visually impaired. Both user groups took part in a synchronous remote usability test. Participants used the same website as in study one. Surprisingly, the results of study two showed that there is no difference between people with visual impairments and nonimpaired users concerning the effects of disability-friendly website design. Both user groups benefitted from recommendations of web accessibility guidelines to a similar extent. These results were in line with study one, indicating that practitioners' negative assumptions concerning disability-friendly website design could not be empirically supported. From the first two studies, we learned that disability-friendly website design can benefit nonimpaired people. We additionally learned that such beneficial effects seem to be similar for people with visual impairments and nonimpaired users. To get a more comprehensive picture of the effects of disability-friendly website design on nonimpaired users, we continued the research plan by investigating possible moderating factors influencing the effects of disability-friendly website design on nonimpaired users.

3.3 Summary of Study Three

Study three aimed to investigate possible moderating factors by focusing on the age of users and the type of device users use. Since we are living in an aging society, and the influence of age in Human-Computer Interaction (HCI) processes gained in importance over recent years (e.g., Jacko, 2012; Rogers & Fisk, 2010; Thatcher et al., 2006), we chose to focus on possible moderating effects of age on the influence of disability-friendly website design on nonimpaired users. Furthermore, over the last years, mobile devices became more and more popular and important for the HCI practice (e.g., Jacko, 2012; Vu & Proctor, 2011), which is why we decided to focus on how the type of device may influence effects of disability-friendly design on nonimpaired users. In a usability test, younger and older users tested the same websites, which were used in study one and two, either on a tablet or a laptop. The findings of study three could support that disability-friendly website design can benefit nonimpaired users.

While age did not influence these beneficial effects, tablet users benefitted more from a high level of disability-friendly website design than laptop users. It is to conclude from study one to three, that we consistently showed beneficial effects of disability-friendly website design on nonimpaired users. The negative concerns about effects of disability-friendly website design on nonimpaired users are thus -according to our findings- not empirically supported. While carrying out study two and three we had discussions with a large number of people participating in the studies. In these discussions, a lot of users with impairments and also older users mentioned that in many cases it is not the visual design that makes the website difficult to use but rather the language complexity of its written content. Therefore, in the fourth and last study, we focused on reduced language complexity as specific disability-friendly website characteristic.

3.4 Summary of Study Four

Study four focused on language complexity as disability-friendly website criterion because several older and visually impaired participants commented that the complexity of the written language is a major issue concerning accessibility. The importance of language complexity was also emphasised in another study, in which 728 people with various impairments were asked about issues in using websites (Ruth-Janneck, 2011). The author concluded that "[…] the most important critical point over all […] is the language in the broadest sense. Accordingly, a large number of users have small or big problems with understanding the provided information. The problems result primarily from the use of difficult language and foreign words" (p. 12). Therefore, we focused in study four on this aspect of disability-friendly website design. In line with our research plan, we investigated whether the use of simplified language on websites has any consequences for nonimpaired people. Similar to study one to three we manipulated a website according to guidelines about easy-to-read language. Participants used either a version with conventional language or a version with easy-to-read language in a usability test. The results showed that there are some benefits of easy-to-read language for nonimpaired users (i.e., improvement in text comprehension) but also disadvantages (i.e., a decrease in text liking). The pattern of effects on nonimpaired users is thus slightly different than in study one to three by also showing negative outcomes for nonimpaired users. Overall, the four studies give a comprehensive overview of possible consequences of disability-friendly website design on nonimpaired users. In the following, fulltexts of the studies are provided, which are integrated further below into a general discussion (see section 4).

Table 4. Overview of the four studies

Study	Main research question	N	Design	Independent variables	Dependent variables	Procedure	Main findings
1	What are the consequences of applying disability-friendly website design for nonimpaired users?	61 (nonimpaired users)	One-factorial	*Disability-friendly website design according to the WCAG 2.0 recommendations:* Levels NA, A, AA	*Performance:* task completion rate, task completion time *Subjective user reactions:* usability, aesthetics, trustworthiness, affect, workload	Usability testing in the lab	High conformance to WCAG 2.0 can provide benefits to nonimpaired users in terms of performance and subjective user reactions
2	Are there different consequences of disability-friendly website design for nonimpaired users than for users with impairments?	110 (55 nonimpaired users, 55 users with visual impairments)	2 x 3	*User condition:* with and without visual impairments *Disability-friendly website design according to the WCAG 2.0 recommendations:* Levels NA, A, AA	*Performance:* task completion rate, task completion time *Subjective user reactions:* usability, aesthetics, user experience, affect, workload	Synchronous remote testing	High conformance to WCAG 2.0 showed similar benefits to nonimpaired users as to users with impairments
3	Do the age of users and the type of device influence the consequences of disability-friendly website design for nonimpaired users?	110 (55 younger adults = 18 – 30 years, 55 older adults = 55 – 82 years)	2x2x2	*Age of users:* younger vs. older adults) *Type of device:* tablet vs. laptop) *Disability-friendly website design according to the WCAG 2.0 recommendations:* Levels NA, AA	*Performance:* task completion rate, task completion time *Subjective user reactions:* user satisfaction	Usability testing at home	High WCAG 2.0 conformance showed similar benefits to younger and older adults. A high level of disability-friendly website design showed most benefits on performance when using a tablet instead of a laptop
4	Are there consequences of easy-to-read language, as disability-friendly website design criterion, for nonimpaired users?	128 (nonimpaired users)	One-factorial	Language complexity (conventional language vs. easy-to-read language)	*Performance:* searching time, reading time, reading speed, detection rate, free recall of content, recognition of content, true/false statements *Subjective user reactions:* usability, aesthetics, affect, workload, text liking, intention to revisit the website, intention to visit the leisure centre	Usability testing in the lab	Applying easy-to-read language in websites can have beneficial and adverse effects on nonimpaired users

Note. N = number of participants; WCAG 2.0 = web content accessibility guidelines 2.0; NA = very low accessibility, A = low accessibility, AA = high accessibility.

3.5 Study One: Implementing Recommendations from Web Accessibility Guidelines: Would they also Provide Benefits to Nondisabled Users[1]

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[1] According to the terminology used in this thesis, the term "nonimpaired users" rather than "nondisabled users" should be used. However, due to printing requirements of the journals, the titles of the four papers comprise the term "nondisabled users", which is in these cases used as an equivalent to the term „nonimpaired users". The paper is reprinted by permission of SAGE publications.

3.5.1 Abstract

Objective: This study examined the consequences of implementing web accessibility guidelines for nonimpaired users.

Background: Although there are web accessibility guidelines for people with disabilities available, they are rarely used in practice. This is partly due to the fact that practitioners believe that they provide no benefits, or even have negative consequences, for people without disabilities, which represent the main user group of websites. Despite these concerns, there is a lack of empirical research on the effects of current web accessibility guidelines on nonimpaired users.

Method: Sixty-one participants without disabilities used one of three websites differing in levels of accessibility (high, low, and very low). Accessibility levels were determined by following established web accessibility guidelines (WCAG 2.0). A broad methodological approach was used, including performance measures (e.g., task completion time) and user ratings (e.g., perceived usability).

Results: A high level of web accessibility led to better performance (i.e., task completion time and task completion rate) than low or very low accessibility. Likewise, high web accessibility improved user ratings (i.e., perceived usability, aesthetics, workload and

trustworthiness) compared to low or very low web accessibility. There was no difference between the very low and low web accessibility conditions for any of the outcome measures.

Conclusion: Contrary to some concerns in the literature and among practitioners, high conformance with web accessibility guidelines may provide benefits to users without disabilities.

Application: The findings may encourage more practitioners to implement WCAG 2.0 for the benefit of users with and without disabilities.

Keywords. Web accessibility, nonimpaired users, WCAG 2.0, performance, usability

3.5.2 Introduction

People with disabilities may face various barriers in their daily activities. For example, a wheelchair user is not able to move up a flight of stairs or a person who has no speech cannot answer a phone. An important activity that may also entail barriers for people with disabilities is the use of the world wide web (web). For instance, hand tremor can make it difficult to click on a link of small size, audio content may not be accessible due to deafness, or low text-to-background contrast cannot be read by users with visual impairments (Vu & Proctor, 2011). About 15 percent of the world's population has some kind of disability (WHO, 2011) and many of these disabilities result in difficulties in using websites (e.g., cognitive-, hearing-, motor- and visual impairments) (Ruth-Janneck, 2011). Thus, a substantial portion of people has restricted or no access to information on websites. This entails considerable disadvantages for the people concerned because of the web's pervasiveness and importance in society.

To overcome this issue, web accessibility (hereafter "accessibility") aims to ensure that "… people with disabilities can perceive, understand, navigate, and interact with the web" (Henry, 2006, p. 2). A typical measure for achieving this objective is the use of guidelines for accessible web design (accessibility guidelines), which recommend specific website characteristics to support users with disabilities. For instance, they recommend using text alternatives for audio content to support users with hearing impairments or suggest a minimum contrast between text and background to support users with visual impairments in reading text (Caldwell et al., 2008). While some studies examined the validity of accessibility guidelines in terms of effects on users with disabilities (e.g., Power, Freire, Petrie, & Swallow, 2012; Rømen & Svanæs, 2012; Ruth-Janneck, 2011), little research focuses on effects of implementing accessibility guidelines for nonimpaired users (Yesilada, Brajnik, Vigo, & Harper, 2013).

Improving our knowledge of their effects on nonimpaired users is important because nonimpaired users also use disability-friendly designed websites and even represent the vast majority of users. A crucial goal in website design is to satisfy as many users as possible (Vu & Proctor, 2011). Consequently, adverse effects on nonimpaired users may hinder the implementation of accessibility guidelines in practice. Conversely, positive side effects on nonimpaired user may encourage practitioners to use accessibility guidelines. Therefore, this study aims to present empirical evidence of the consequences of implementing accessibility guidelines recommendations for nonimpaired users.

3.5.2.1 Web Content Accessibility Guidelines

Web content accessibility guidelines are a tool that can be used for creating content considering the needs of people with disabilities or for evaluating a website concerning accessibility (Chisholm & Henry, 2005). The most commonly used set of accessibility standards is the web content accessibility guidelines 2.0 (WCAG 2.0; Caldwell et al., 2008). It has found its way into the laws of several countries, such as Australia, Canada, Germany, Japan and Hong Kong (Rogers, 2015) and constitutes the international standards organization's standard for accessibility (ISO 40500, 2012). The WCAG 2.0 comprises 61 success criteria (SC), which provide specific recommendations on how to make web content accessible to users with different impairments (e.g., cognitive-, hearing-, visual and physical impairments). For instance, all functionalities should be available from keyboard or captions should be used to describe audio content. Each SC can be tested for whether it is satisfied. According to the degree of conformance with these SC, websites can be classified into one of three categories: low accessibility (A), high accessibility (AA) and highest accessibility (AAA) (see Caldwell et al., 2008 for details). According to WCAG 2.0, level-A or higher may be considered 'accessible'. Hence, we will term websites non-accessible (NA) if they offer lower conformance than level-A.

3.5.2.2 Rationale for Implementing Accessibility

The application of WCAG 2.0 in practice is still rare. In recent studies, more than 95% of websites investigated were classified as NA (e.g., Gonçalves, Martins, Pereira, Oliveira, & Ferreira, 2013; Nurmela, Pirhonen, & Salminen, 2013). Among practitioners, reasons for implementing accessibility have been market benefits, legal requirements, the intention to be inclusive, and to design better products (Farrely, 2011; Loiacono & Djamasbi, 2013; Yesilada, Brajnik, Vigo, & Harper, 2012). Practitioners also reported reasons hindering accessibility implementation, including lack of financial benefits and no demand of clients and management

(Farrelly, 2011; Freire, Russo, & Fortes 2008; Lazar, Dudley-Sponaugle, & Greenidge, 2004). Another issue that may prevent practitioners from applying accessibility is prevailing negative beliefs about disability-friendly design. Such beliefs have already been extensively discussed in the literature (see Ellcessor, 2014 for a review). This includes the beliefs that accessible websites are ugly and boring (e.g., Lawson, 2006; Petrie, Hamilton, & King, 2004) and that accessibility only provides benefits to a small number of users (e.g., Mlynarczyk, 2012).

Against this background, knowing more about effects of accessibility on nonimpaired users may be important for decisions on implementing accessibility in practice. Particularly, positive effects of accessibility on nonimpaired users would be in line with reasons for implementing accessibility (e.g., market benefits or being inclusive) because a wide range of users would be positively affected. In addition, since practitioners mention legal requirements to be an important reason for implementing accessibility (Loiacono & Djamasbi, 2013), it is to be expected that the number of websites conforming WCAG 2.0 will grow, due to the dissemination of these guidelines by means of different national laws (e.g., Murphy, 2013). As this will lead to an increase in the number of accessible websites available to nonimpaired users, it is important to investigate possible side effects of disability-friendly design on this user group. Given these considerations, previous studies suggest a need to empirically examine the consequences of implementing accessibility in websites for nonimpaired users (e.g., Yesilada et al., 2012, 2013).

3.5.2.3 Research on Accessibility with Nonimpaired Users

One of the first studies that stated a relation between accessibility and nonimpaired users focused on the visual design of websites (Petrie et al., 2004). Fifty-one users with disabilities evaluated the accessibility of 100 websites by reporting problems encountered. The authors discussed the problems identified in regard to visual design, concluding that accessibility referred to aspects of visual design that may also pertain to nonimpaired users (e.g., color contrast or visual structure). In line with this conclusion, Mbipom (2009) showed that websites with high ratings on certain dimensions of aesthetics (i.e., being clear, clean and organized) violated fewer WCAG 1.0 criteria (first version of the WCAG; http://www.w3.org/TR/WCAG10/) than websites with lower ratings of aesthetics. Another study compared users who were blind to nonimpaired users regarding task completion rate and time (Disability Rights Commission, 2004). Both user groups solved tasks on three websites with high accessibility ratings (according to WCAG 1.0) and three websites with low ratings. While users who were blind solved more tasks on highly accessible websites, nonimpaired users' task completion rate was not affected by accessibility level. Of particular interest was the results that both user groups were faster using highly accessible websites compared to websites with low accessibility. Further work suggested that users with disabilities and nonimpaired users may encounter similar problems but the impact may be stronger on users with disabilities (Petrie & Kheir, 2007). In their study, six users who were blind and six nonimpaired users were compared regarding problems in using websites. All participants solved tasks on two websites and were asked to report occurring problems. Results showed that about 15% of the problems reported were encountered by both user groups. Although the overlap appears to be rather small, it confirmed that users with and without disabilities may be affected by the same website characteristics. Further research showed that high WCAG 1.0 conformance led to higher usability ratings by nonimpaired users compared to low conformance (Huber & Vitouch, 2008) and also to higher scores in automated usability testing (Sullivan & Matson, 2000). However, there is also work that did not find a relationship between WCAG 1.0 conformance and subjective ratings or performance of nonimpaired users (Arrue, Fajardo, Lopez, & Vigo, 2007). While the vast majority of studies were based on WCAG 1.0, there is also recent work that made use of the improved guidelines WCAG 2.0 when examining nonimpaired users (Pascual, Ribera, Granollers, & Coiduras, 2014). They compared an A-website to an NA-website with regard to performance and subjective measures. The sample consisted of four nonimpaired users and nine visually impaired users. For nonimpaired users, all performance measures and subjective measures showed similar means for the A-website and the NA-website. Users with visual impairments completed more tasks on the A-website than on the NA-website, and they were also faster in doing this.

Similar to the approach of the present work, research in a related field (i.e., designing for older adults) investigated possible positive side effects of design recommendations. It emerged that designing for older adults may also benefit younger adults (e.g., Chadwick-Dias, McNulty, & Tullis, 2003; Johnson, & Kent, 2007; Pak, & Price, 2008; Westerman, Davies, Glendon, Stammers, & Matthews, 1995). Furthermore, website design recommendations for older adults (e..g, Badre, 2002; Rogers, & Fisk, 2001; Mead, Lamson, & Rogers, 2002) overlap considerably with the recommendations of WCAG 2.0 (e.g., high contrast, intuitive link texts, consistent design or left aligned text). Given the overlap between the design for older adults and accessibility recommendations, and considering the fact that design for older adults will also provide benefits to younger adults, it is conceivable that accessibility will also have positive side effects on nonimpaired users.

Overall, previous research reported a positive influence of accessibility for nonimpaired users. The studies reviewed provide important first insights into the effects of accessibility on nonimpaired users, but there are still some knowledge gaps. First, it is to be noted that all studies reported (except Pascual et al., 2014) were conducted before the release of WCAG 2.0 in 2008, being based on WCAG 1.0 as a reference standard. This is important because WCAG 2.0 differs considerably from WCAG 1.0 (Reid & Snow-Weaver, 2008, 2009). Hence, research results based on WCAG 1.0 need to be treated with some caution. Second, most studies investigated rather small samples of nonimpaired users (e.g., Pascual et al. (2014); $n = 4$, Petrie & Kheir, 2007; $n=6$) or did not include nonimpaired users (e.g., Petrie et al., 2004; Sullivan & Matson, 2000). This suggests a strong need for studies with larger samples of nonimpaired users. Third, studies that investigated performance (e.g., task completion time) of nonimpaired users mainly reported descriptive statistics (i.e., means or percentages) and conducted no inferential statistical tests (e.g., Disability Rights Commission, 2004; Pascual et al., 2014). Such inferential statistical analyses should be conducted. Fourth, most studies emphasized ecological validity by examining various real websites with different levels of accessibility (e.g., Pascual et al., 2014; Petrie & Kheir, 2007). Although studies with high ecological validity are important for the practical application, research also needs to use more controlled experiments, to gain further insights into the effects of accessibility on nonimpaired users. Fifth, until now none of the studies that addressed accessibility and nonimpaired users had measured a broader range of outcome variables, using both objective measures (e.g., task completion time) and subjective ones (e.g., perceived usability). Such a broader measurement approach may help gain a more comprehensive understanding of the influence of accessibility on nonimpaired users.

3.5.2.4 The Present Study

The goal of this experiment was to examine the consequences of implementing recommendations from current accessibility guidelines (i.e., WCAG 2.0) for nonimpaired users. As an independent variable, accessibility was manipulated by modifying 13 WCAG 2.0 recommendations in an existing municipal website, resulting in three versions of the website with different levels of accessibility: levels AA, A, and NA. Level-AAA was not included because of its rare prevalence in practice (e.g., Nurmela, Pirhonen, & Salminen, 2013). Apart from WCAG 2.0 conformance, the websites were identical (e.g., same content and same number of menu items). The websites were evaluated by means of a usability test, taking a range of performance measures (task completion time and task completion rate) and subjective ratings (usability, aesthetics, trustworthiness, affect, and workload).

Based on the literature review, beneficial effects of accessibility on performance and subjective measures were expected for nonimpaired users. More specifically, it was predicted that level-AA and level-A would lead to lower task completion time, higher task completion rate, and higher perceived usability than level-NA. Furthermore, it was assumed that level-AA and level-A would result in higher ratings of aesthetics, trustworthiness and positive affect but lower ratings of negative affect and workload than level-NA. Overall, the more the website corresponded to the guidelines, the higher we expected ratings and performance to be (i.e., NA < A < AA).

3.5.3 Method

3.5.3.1 Participants and Design

Sixty-one participants took part in the study (see table 5 for details). Participants were students or recent graduates. They were unpaid, but students received credits for their participation. We required participants to have normal acuity (with or without glasses) and color vision (i.e., no visual impairment diagnosed by a physician or registered by health insurance). We relied on self-report data from participants, and no vision test was conducted.

The study employed a one-factorial between-subjects design, in which a website was manipulated at three levels of WCAG 2.0 conformance: level-NA (very low conformance), level-A (low conformance) and level-AA (high conformance).

Table 5. Overview of the sample for the three accessibility conditions

Sample characteristics	**Total**	**NA-website**	**A-website**	**AA-website**	***F*(df)**	***p***
Participants *n*	61	21	20	20	n.m	n.m
Women *n* (%)	48 (78.7)	13 (61.9)	17 (85.0)	18 (90.0)	n.m	n.m
Age *M* (*SD*)	21.4 (2.4)	21.8 (3.6)	21.5 (1.5)	21.1 (1.6)	0.5 (2, 60)	.62
Education *M* (*SD*)	12.5 (1.4)	12.6 (1.6)	12.0 (0.0)	12.8 (1.8)	1.6 (2, 60)	.21

Note. NA = very low conformance; A = low conformance; AA = high conformance; Education = years of education; ANOVA = Analysis of variance; n = number of participants; *M* = mean; *SD* = standard deviation; % = percentage of participants, n.m = not measured

3.5.3.2 The Websites – Content and Characteristics

The websites are based on a municipal website of a town in the country of Liechtenstein (www.eschen.li). This website is certified as AA-website according to WCAG 2.0. The website contains mainly text information, pictures, and a contact form. There is no multimedia content available, such as video (the webcam and map function provided by the original website were removed for testing). Furthermore, the website is primarily based on Hypertext Markup Language (HTML) as well as Cascading Style Sheets (CSS) and contains little JavaScript. The size of the original website was slightly reduced (i.e., seven pages of no relevance for the present study were removed) and three copies of the website were made. The design of one website remained similar to the original corresponding to WCAG 2.0 level-AA. The two further copies were adapted according to level-A and level-NA (see figure 3 for screenshots).

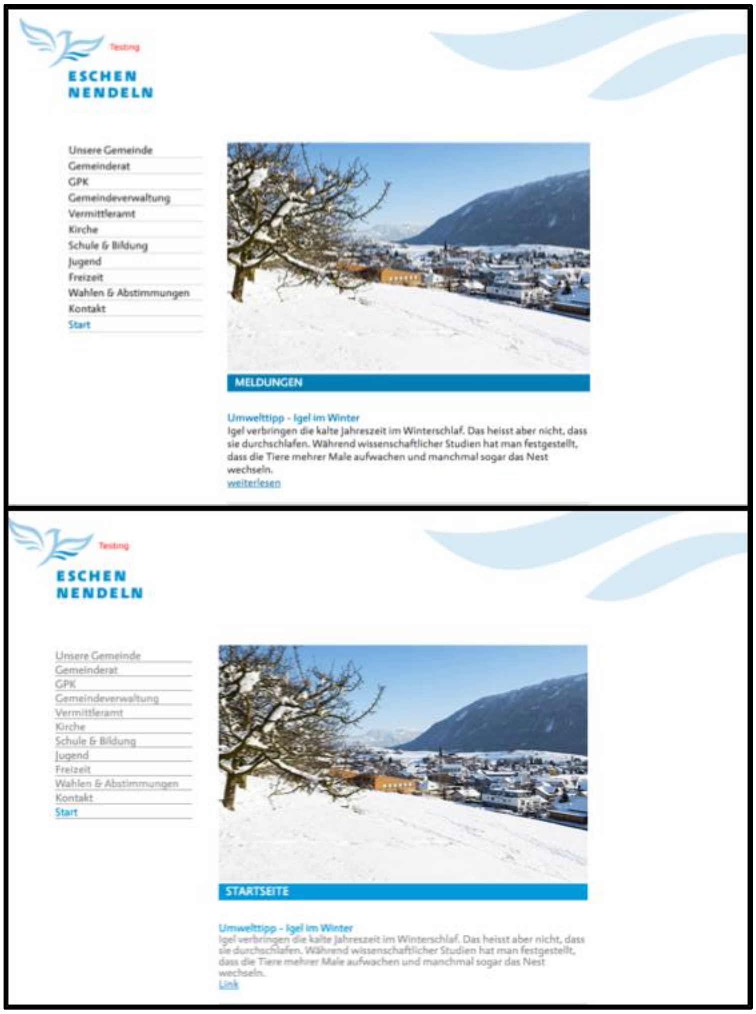

Figure 3. *Screenshots of the home page of the website used for testing (top: level-AA, bottom: level-NA)*

3.5.3.3 The Websites - Manipulation

Several steps were taken to obtain manipulations corresponding to level-A and level-NA. First, we had initial discussions with accessibility experts about success criteria relevant to practitioners and possible manipulations of the website. These experts were two web developers with several years of work experience in accessibility and design, and a member of the non-profit organization *Access for All*. *Access for All* is the competence center for accessibility in Switzerland and responsible for the official certification of websites according to WCAG 2.0. Second, we aimed to identify frequent violations of WCAG 2.0 recommendations by reviewing the literature and the document "Understanding WCAG 2.0" (Cooper, Kirkpatrick, & O Connor, 2014), and by screening 500 municipal websites. This resulted in 10 websites characteristics being chosen, which were considered relevant to the present study. For the A-website the following characteristics were manipulated: contrast, text alignment, precision of link description, appropriateness of headings, focus visibility, number of section headings, and consistency in link style. Additionally, the following characteristics were manipulated for the NA-website: precision of form description, focus order, and error identification (see appendix S1a for details). Third, we had repeated discussions with the experts on how to adapt and implement common failures in websites for the low and very low accessibility conditions. Note that the chosen criteria were considered to be typical accessibility characteristics of particular relevance based on earlier empirical work (e.g., Freire, Petrie, & Power, 2011; Power et al., 2012; Rello, Kanvinde, & Baeza-Yates, 2012; Ruth-Janneck, 2011). A further reason for choosing these criteria, was that most of the criteria were of general relevance because it has been shown that they also provide benefits to other user groups, such as older users (e.g., Chadwick-Dias, & Tullis, 2003; Johnson, & Kent, 2007; Kurniawan, & Zaphiris, 2005; Nayak, Priest, Stuart-Hamilton, & White, 2006; Sayago, Camacho, & Blat, 2009).

3.5.3.4 Manipulation Check

In order to validate the manipulations of the websites, we did additional testing by using a synchronous remote method (using screen sharing technology called TeamViewer, cf. Andreasen et al., 2007; Dray & Siegel, 2004). In a two-factorial between-subjects design, 55 users without visual impairments (age: $M = 45.1$; $SD = 14,8$; range = 22 – 71) and 55 users with visual impairments (i.e., a maximum eyesight of 20% on the better eye; age: $M = 45.9$; $SD = 13.\ 8$; range = 22 – 73) used the three websites. The sample of visually impaired users included 38 (69%) users who were blind and 17 (31%) users with impaired eyesight. All of the blind users employed screen reading software or a combination of a screen reader with a braille keyboard (65%). All of the 17 users with impaired eyesight used assistive tools. One user only used a screen reader, nine users only used a screen magnifier, three users used a screen reader in combination with a screen magnifier, and four users reported that they used an assistive tool without specifying it. Each participant completed five information search tasks on one of three websites (NA, A or AA) and provided subjective ratings afterwards. The tasks were similar to those used in the present study (see table 6). The subjective ratings had two aims: To determine whether the created websites were reasonable and to verify whether the accessibility manipulations benefitted people with disabilities (i.e., visual impairments).

The first rating aimed to validate whether the manipulations were reasonable and comparable to websites found on the internet ("How was the overall quality of the website compared to websites you usually use?"; possible answers were: much worse (1), worse (2), equal (3), better (4), much better (5)). Since we downgraded the websites from level AA to A and NA, the aim of this question was to check whether the websites were not unrealistically downgraded. Having reasonable manipulations would thus imply that people with or without disabilities would rate the A- and NA-website similar in quality to typical websites found on the internet. The results confirmed that the confidence intervals for both websites included a score of 3, which indicated that the NA- and A-website did not differ significantly from the mean position of the scales (i.e., 3). Hence, participants perceived these website to be similar in quality to websites they usually use (NA-website: $M = 2.71$ ($SD = 0.87$), $CI = 2.40 - 3.01$; A-website: $M = 3.03$ ($SD = 0.77$), $CI = 2.77 - 3.29$). This finding was supported by a separate analysis for the users with and without disabilities. Ratings of users with visual impairments did not differ significantly between level-NA and A ($t = 0.85$, $df = 33$, $p > .05$; NA-website: $M = 2.88$ ($SD = 0.99$); A-website: $M = 3.17$ ($SD = 0.99$)). Likewise, the ratings of nonimpaired users did not differ significantly between level-NA and A ($t = 1.74$, $df = 27$, $p > .05$; NA-website: $M = 2.53$ ($SD = 0.72$); A-website: $M = 2.89$ ($SD = 0.47$)).

The second item aimed to examine the effect of the accessibility manipulations on users with visual impairments. Therefore, participants with visual impairments additionally rated the usability of the website by answering the question: "How usable was the website overall?" The response scale ranged from 1 (not at all) to 5 (very). Having valid accessibility manipulations implies that people with visual impairments give the lowest usability rating to the NA-website, followed by the A-website and the best rating to the AA-websites. The results clearly confirmed this pattern with a highly significant effect $F(2, 52) = 13.15$; $p < .001$ (NA-website: $M = 3.24$ ($SD = 0.90$); A-website: $M = 4.00$ ($SD = 0.84$); AA-website: $M = 4.60$ (SD

= 0.68)). Post hoc analyses with Bonferroni corrections revealed a significant difference between level-NA and level-A (p = .02), and between level-NA and level-AA ($p < .001$). Level-A and AA did not differ significantly ($p > .05$), which was to be expected because the majority of participants were blind. Most of the criteria for level-AA aim to support users with impaired eyesight rather than blind people, whereas most level-A criteria aim to support blind users (Cooper et al., 2014). The manipulation check thus confirmed that the websites were suitable and valid for manipulating the level of accessibility in a realistic manner.

3.5.3.5 Measures

Performance Measures. Two measures were taken to assess performance: (a) Task completion time, defined as the time (s) used to complete a given task and (b) task completion rate (% of tasks successfully completed).

Subjective Measures. Five established questionnaires were used to take the subjective measures. For all of them German-language versions of the questionnaires were employed: (a) perceived usability was measured by the website Analysis and MeasureMent Inventory (WAMMI; Kirakowski, Claridge, & Whitehand, 1998). (b) Perceived aesthetics was assessed by the visual aesthetics of websites inventory (VisAWI; Thielsch, Moshagen, & Schloss, 2011). (c) To measure the perceived trustworthiness of the website, a five-item subscale of the Scale for Online Users' Trust was used (Bär, 2014). (d) Positive and negative affect was assessed by the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). (e) Subjective workload was measured by the NASA Task Load Index (NASA TLX; Hart & Staveland, 1988).

3.5.3.6 Procedure

The experiment took place in a usability lab at the University of Fribourg. Before beginning the experiment, the landing page of the website was briefly shown to participants to check that they did not know the website (none of the participants had seen it before). Afterwards, five tasks had to be completed (see table 6). If a task was not completed after four minutes, the experimenter helped the participant solve the task. In such a case, task completion time was set to a default value of 4 minutes and task completion was scored as being unsuccessful. Participants began the experiment by filling in a questionnaire about their current positive and negative affect (PANAS). While using the websites, a screen-recording software was used to assess task completion time and completion rate. After completing the tasks, each participant completed the PANAS again, followed by further questionnaires (i.e., WAMMI, VisAWI, SCOUT, NASA-TLX and a demographic questionnaire).

Table 6. Tasks to be completed on the website

Task	Description
1	Identify the bus service that will take you to the sports center.
2	Fill out a form to order firewood from the municipality.
3	Find the e-mail address of the person responsible for education in town.
4	Identify the motorway that connects this town with Switzerland.
5	Find a phone number to book the barbecue area for a group event.

3.5.3.7 Materials

Testing was conducted on a MacBook Pro (13'', Intel HD Graphics 4000) with an external mouse. The websites were navigated with the browser Mozilla Firefox 26.0.

3.5.3.8 Data Analysis

We conducted a one-factorial analysis with level of accessibility as an independent variable. Post hoc tests with Bonferroni adjustment were used to determine differences between the three experimental conditions (low accessibility, medium accessibility, high accessibility).

For measuring changes in positive and negative affect, a baseline measurement by the PANAS was taken. This baseline measurement was then used as a covariate for analyzing positive and negative affect after website use.

An outlier analysis was carried out for each dependent variable, employing the median absolute deviation (MAD) method (Leys, Ley, Klein, Bernard, & Licata, 2013). This method is robust and especially recommended for experiments with small to medium sample sizes. A conservative threshold of 3 was chosen (Miller, 1991). Four outliers (6.6%) were detected for perceived usability and one (1.6%) for trustworthiness. They were not included in the respective data analysis.

Due to technical problems, a video file was lost. Therefore, the performance data of one participant was not included in the analysis.

3.5.4 Results

3.5.4.1 Performance Measures

Task Completion Rate. Table 7 shows that there were differences in completion rates as a function of WCAG 2.0 conformance. The effect was significant, $F(2, 57) = 7.38$, $p = .001$, partial-$\eta^2 = .21$. As predicted, completion rate was highest for the AA-website. Post hoc tests revealed significant differences between condition AA and A ($p = .016$; $r = .43$) as well as between AA and NA ($p = .004$; $r = .52$). There was no significant difference between A and NA.

Task completion time. As expected, task completion time decreased with higher WCAG 2.0 conformance (see table 7). The effect of WCAG 2.0 conformance on task completion time was significant, $F(2, 57) = 3.74$, $p = .03$, partial-$\eta^2 = .11$. Post hoc tests showed a significant difference between level-AA and level-NA ($p = .03$; $r = -.50$). There was no further significant difference in pairwise comparisons.

Table 7. Performance measures as a function of WCAG 2.0 conformance levels: means, (standard deviations) and [confidence intervals]

Measures	NA-website	A-website	AA-website
Task Completion Rate(%)**	65.0 (15.7)	68.6 (16.5)	82.1 (12.2)
Confidence Interval	[58.3, 71.6]	[61.9, 75.2]	[75.5, 88.8]
Task Completion Time (s)*	136.8 (21.9)	125.95 (27.9)	116.9 (18.3)
Confidence Interval	[126.5, 147.2]	[115.6, 136.3]	[106.6, 127.2]

Note. NA = very low conformance; A = low conformance; AA = high conformance; * $p < 0.05$ (2-tailed); ** $p < 0.01$ (2-tailed); n.s. = non-significant.

3.5.4.2 Subjective Measures

Usability. In line with our hypothesis, Table 8 shows that ratings for perceived usability were highest for the AA-website. The effect on perceived usability was significant $F(2, 54) = 5.18$, $p = .009$, partial-$\eta^2 = .16$. According to post hoc tests, level-AA differed significantly from level-A ($p = .015$; $r = .41$) and also from level-NA ($p = .018$; $r = .36$). The difference between level-A and NA was not significant.

Aesthetics. WCAG 2.0 conformance showed a significant effect on perceived aesthetics $F(2, 58) = 4.23$, $p = .019$, partial-$\eta^2 = .13$. Again, highest ratings were given for level-

AA. As presented in table 8, post hoc tests showed that AA was significantly different from A (p = .023; r = .47). There were no further significant pairwise comparisons.

Trustworthiness. The effect of WCAG 2.0 conformance on perceived trustworthiness was also significant $F(2, 57) = 3.47$, $p = .038$, partial-$\eta^2 = .11$. Participants gave highest ratings for level-AA, whereas ratings in condition A and NA were similar (see table 8). However, post hoc tests did not reveal any significant pairwise comparison.

Affect. The data for both measures of affect are shown in table 8. Accessibility did not show an effect on positive affect $F(2, 57) = 2.25$, $p = .115$, partial-$\eta^2 = .07$. The same applied to negative affect, $F(2, 57) = 0.371$, $p = .691$, partial-$\eta^2 = .01$.

Workload. As predicted, ratings of perceived workload were lowest for the AA-website (see table 8). The effect on perceived workload was significant, $F(2, 58) = 6.23$, p = .004, partial-$\eta^2 = .18$. As shown in table 8, post hoc tests revealed a significant difference between condition AA and NA (p = .005; r = - .45); between the levels AA and A (p = .024; r = - .38) but not between the other WCAG 2.0 levels (see Table 8). An analysis of the subscales of the workload questionnaire revealed that accessibility affected the dimensions mental demands ($F(2, 58) = 7.25$, $p = .002$, partial-$\eta^2 = .2$) and effort ($F(2, 58) = 7.6$, $p = .001$, partial-$\eta^2 = .2$) but none of the other dimensions (see Table 9).

Table 8. Subjective measures as a function of WCAG 2.0 conformance levels: means, (standard deviations), and [confidence intervals]

Measures	**NA-website**	**A-website**	**AA-website**
Usability (1-5)**	2.8 (0.5)	2.8 (0.3)	3.3 (0.7)
Confidence Interval	[2.6, 3.1]	[2.5, 3.1]	[3.1, 3.6]
Aesthetics (1-7)*	4.6 (1.1)	4.3 (0.8)	5.1 (0.8)
Confidence Interval	[4.2, 5.0]	[3.9, 4.7]	[4.7, 5.6]
Trustworthiness (1-5)*	3.7 (0.8)	3.7 (0.5)	4.1 (0.6)
Confidence Interval	[3.4, 3.9]	[3.5, 4.0]	[3.9, 4.4]
Workload (1-20)*	10.9 (2.1)	10.5 (2.3)	8.4 (2.9)
Confidence Interval	[9.9, 12.0]	[9.4, 11.6]	[7.3, 9.5]
Positive affect (1-5) n.s.	2.6 (0.6)	2.5 (0.8)	2.6 (0.6)
Negative affect (1-5) n.s.	1.3 (0.3)	1.5 (0.6)	1.3 (0.4)

Note. NA = very low conformance; A = low conformance; AA = high conformance. * $p < 0.05$ (2-tailed); ** $p < 0.01$ (2-tailed); n.s. = non-significant.

Table 9. NASA-TLX subscales as a function of WCAG 2.0 conformance levels: means, (standard deviations), and [confidence intervals]

Measures	**NA-website**	**A-website**	**AA-website**
Mental demands (1-20)**	13.5 (2.1)	11.9 (3.0)	9.6 (4.6)
Confidence Interval	[12.1, 15.0]	[10.4, 13.4]	[8.1, 11.1]
Effort (1-20)**	12.4 (2.3)	11.6 (3.4)	8.2 (4.8)
Confidence Interval	[10.8, 14.0]	[9.9, 13.2]	[6.6, 9.8]
Physical demands (1-20) n.s.	7.1 (5.1)	5.2 (5.2)	4.9 (3.4)
Temporal demands (1-20) n.s.	10.0 (3.5)	10.9 (4.3)	9.15 (4.4)
Performance (1-20) n.s.	8.9 (4.1)	9.0 (4.3)	11.4 (5.0)
Frustration (1-20) n.s.	10.5 (4.7)	11.6 (5.3)	9.0 (6.0)

Note. NA = very low conformance; A = low conformance; AA = high conformance. * $p < 0.05$ (2-tailed); ** $p < 0.01$ (2-tailed); n.s. = non-significant.

3.5.5 Discussion

The study aimed to investigate consequences of implementing accessibility guidelines for nonimpaired users. Employing websites based on the current accessibility guidelines (i.e., WCAG 2.0), a standardized experimental approach was used to test nonimpaired users, using a larger sample of nonimpaired users than previous studies. Measures of performance (i.e., task completion time and task completion rate) and user ratings (i.e., perceived usability, aesthetics, workload, trustworthiness, and affect) were taken. A website was modified to meet the three WCAG 2.0 conformance levels (i.e., NA, A and AA). It was expected that increasing WCAG 2.0 conformance would benefit user performance and user evaluations. The AA-website showed advantages over the two other websites with regard to performance and subjective evaluations. No differences were found between NA and A.

3.5.5.1 Performance

The present results supported the assumption that a website's higher WCAG 2.0 conformance would lead to higher task completion rates and lower task completion time. Participants using the AA-website were more successful in solving tasks and were faster in doing so than participants who used website A or NA. The results are in line with previous work, which also showed an increase in performance of nonimpaired users with higher accessibility (Disability Rights Commission, 2004; Petrie & Kheir, 2007) and no difference between NA and A (Pascual et al., 2014).

3.5.5.2 Subjective Measures

It was hypothesized that participants' evaluations would be more positive for websites with higher WCAG 2.0 conformance than for websites with lower conformance. As predicted, participants using the AA-website gave higher ratings of usability, aesthetics, trustworthiness and lower ratings in workload than participants in the other conditions. For most of the dependent variables, the post hoc analysis revealed that there was a difference between level AA and NA but not between the other conditions. These results correspond to the findings of previous work showing that higher WCAG 1.0 conformance is also positively associated with perceived usability of nonimpaired users (Huber & Vitouch, 2008). Furthermore, the present results support Petrie et al.'s (2004) view that accessibility can influence visual design. The finding that accessibility is positively related to aesthetics found for WCAG 1.0 (Mbipom, 2009) is now replicated for WCAG 2.0.

A closer look into the relationship between accessibility and workload revealed that only the dimensions mental demands and effort were affected by the accessibility manipulation. The other dimensions of the NASA-TLX, physical demands, temporal demands, own performance, and frustration, were not significantly influenced by different levels of accessibility. According to the WCAG 2.0, the aim of the manipulated recommendations is to increase the understandability (e.g., criteria 1.3.1 "info & relationship" or criteria 1.4.8 "visual presentation"), operability (e.g., criteria 2.4.4 "link purpose" or criteria 2.4.10 "section headings") and understandability (e.g., criteria 3.4.4 "consistent identification" or criteria 3.3.1 "error identification") (see appendix S1a for descriptions of the criteria) (Cooper et al., 2014). It is thus in our opinion plausible that these recommendations reduce mental demands and effort by providing a clearer structure of the website (e.g., by providing section headings), increasing predictability (e.g., due to purposeful link texts), or higher distinguishability of elements (e.g., by a consistent usage of styles for website elements). This assumption is supported by previous research, which showed that reducing complexity in websites is associated with lower perceived workload (e.g., Schmutz, Heinz, Métrailler, & Opwis, 2009). Physical and temporal demands were not affected because browsing a website is usually not physicallycally demanding and there was no obvious time limit for solving the tasks. Participants might thus not have experienced time pressure. An effect on frustration might not have occurred because participants did not receive feedback about their performance. Additionally, it was emphasized that the experiment focused on the evaluation of the website and did not examine the performance of participants. This may also explain the lack of an effect on perceived performance. Since to our knowledge, there is no other study focusing on the relationship of accessibility and workload, these associations may need to be investigated further.

Similarly, no study has related accessibility to perceived trustworthiness of nonimpaired users. However, an earlier study found well-structured content (e.g., possible sequence of clicks and paths on websites) is an important antecedent of trust in websites (Bart, Shankar, Sultan, & Urban, 2005). This might explain the effects of accessibility on trust because in the presented study the manipulated accessibility recommendations may have also influenced the structure of the website in a similar way (e.g., by providing section headings, meaningful labels, and purposeful link texts).

3.5.5.3 Relevant Success Criteria for Nonimpaired Users

An interesting finding was that effects on nonimpaired users only occurred when changing the website from NA to AA but not from NA to A or from A to AA. We thus assume that the combination of changes on level A and level AA is responsible for positive effects on nonimpaired users and that there is not a single dominant criterion (e.g., link text) that caused the effect. In case of a single dominant criterion, effects would have occurred either between NA and A or between A and AA. Nevertheless, we assume that some criteria were more important than others (e.g., users rarely used tabbing, which suggests that changing tabbing order was not relevant to the present results). The remaining criteria may jointly benefit nonimpaired users by providing support in reading (i.e., contrast and text alignment), completing a form (i.e., form labeling and error identification), and navigating by providing clear structure (i.e., meaningful headings and link texts). User comments in post-experimental interviews support the assumption of a combined effect of success criteria because participants mainly gave general comments such as “good structure” or “very clear website” for the AA-website and “sometimes unclear structure” or “a rather complex website” for the NA-website. Nobody mentioned a specific issue such as unclear link text or low contrast.

3.5.5.4 Common Recommendations for Users with and without Impairments

It is important to note that many accessibility requirements found in WCAG 2.0 are also recommended in guidelines for designing user-friendly websites or interfaces for nonimpaired people (e.g., Farkas & Farkas, 2000; Nielsen, Tahir, & Tahir, 2002; Shneiderman, 2010; Spool, 1999; Spyridakis, 2000; Williams, 2000). Examples for such recommendations are: use precise link texts, use headings to structure the content, use consistent design and use left aligned text. The overlap between recommendations for accessibility and recommendations for good website design for nonimpaired users strengthens our assumption of beneficial effects of accessibility on nonimpaired users and may partly explain the present results.

3.5.5.5 Limitation and Future Research

The present study has some limitations. First, to complement previous research, we chose a controlled experimental approach by manipulating a single website according to different accessibility levels with a view to eliminating website characteristics that are not related to accessibility guidelines (e.g., differences in written content, images or type of website). The downside of this approach is that the NA- and A-websites used do not actually exist. However, we tried to obtain reasonable representations of level NA and A by considering the literature on typical accessibility issues, and we used existing websites as a reference for our manipulations. Furthermore, the validation study revealed that the manipulations were reasonable for users with and without disabilities. We think that studies emphasizing high experimental control should complement (though not replace) work focusing on ecological validity. Therefore, future research should pursue both paths. Second, the type of website used in the present study (an existing local government website) is not necessarily representative of the wide range of websites found on the web. For example, the website did not contain any multimedia content (e.g., video content) or interaction elements (e.g., drag and drop or captcha). Manipulating the accessibility of such website features may result in different effects on nonimpaired users and need to be addressed in future research. Nevertheless, the characteristics of the website used in this study are comparable to many types of websites, including websites of industry, educational institutions, blogs, and news. Third, user ratings may not be sufficient to gauge complex concepts, such as affect or aesthetics. Future research could take this into account by using subjective measures together with objective measures (e.g., physiological measures for assessing emotional reactions). Fourth, accessibility is a complex concept with different components, such as users, developers, and content (Chisholm & Henry, 2005). Therefore, future research should compare effects of accessibility guidelines on both nonimpaired users and people with disabilities rather than focussing on nonimpaired users alone. This will allow us to gain a deeper understanding of the relation between accessibility and nonimpaired users. Fifth, since the sample comprised young students, the generalizability of present results to a more heterogeneous population may be limited. Future research may investigate effects of accessibility on nonimpaired users from a wider range of age and educational level. However, we would expect even stronger effects of accessibility on older or less educated samples because they might be less experienced in using websites than young students and would benefit more from supportive website characteristics.

3.5.5.6 Implications for Practitioners

The present study has important implications for practice. First, WCAG 2.0 should not only be considered as an aid for designing websites according to the needs of users with disabilities but also as a helpful tool for designing more usable websites for nonimpaired users. This different framing may motivate practitioners to apply these guidelines more often (because of the benefits to nonimpaired users) while alleviating the financial concerns of practitioners about website accessibility. As an implication for the guidelines, positive effects for users without disabilities should be mentioned explicitly as well as the fact that level AA is of particular importance for such users. Second, the consistent pattern of beneficial effects of level AA compared to NA is highly relevant to practitioners. Currently, most of the websites conform to level NA (e.g., Gonçalves, Martins, Pereira, Oliveira, & Ferreira, 2013; Nurmela, Pirhonen, & Salminen, 2013), which shows that there is much room for improvement. Practitioners should aim for an upgrade from level NA to AA rather than A (since the latter would not provide noticeable benefits). The effect sizes between the conditions NA and AA were consistently medium to large. For instance, the AA-website led to a mean decrease in task completion time of about 20s (i.e., 15%) and increased the task completion rate by about 17%. Third, the 10 SC that were changed from level NA to AA are rather easy to implement (e.g., meaningful link text, sufficient contrast, text alignment). These 'easy-to-be-changed'-criteria may help practitioners improve websites or design new ones, following WCAG 2.0 by offering a positive cost-benefit trade-off.

3.5.5.7 Conclusion

The present work demonstrated that implementing accessibility guidelines can provide several benefits for nonimpaired users. To achieve this, high conformance (i.e., level-AA) to current guidelines (i.e., WCAG 2.0) is necessary. Overall the research field of accessibility still seems to be virgin territory despite its important impact on society and the considerable number of users that are affected. Especially effects of accessibility standards on various user groups have been hardly addressed. The present work has thus some elements of an exploratory study, which may initiate further research into this issue. This is important because further knowledge might lead to increasing awareness and acceptance of accessibility in research and practice. We hope that our research represents a contribution to increasing the prevalence of accessible websites and, more generally, to the promotion of equality.

3.5.6 Appendix – Study One

Appendix S1a. Overview of website characteristics manipulated

Success criterion (WCAG 2.0 level)	**AA-website**	**A-website**	**NA-website**	**Comments – reference to the document Understanding WCAG 2.0**
1.1.1 Non-text content (A)	Every image on the website has an appropriate text alternative	Every image on the website has an appropriate text alternative	For every image, the text alternative “image” was used	The manipulation is based on common failures F30 and F39 (Manipulated for further studies - Did not affect nonimpaired users)
1.3.1 Info and relationships (A)	Required fields in the contact form were labeled with bold text and with an asterisk whose text alternative says, "required".	Required fields in the contact form were labeled with bold text and with an asterisk whose text alternative says, "required".	**Required fields were labeled only with bold text, whose text alternative did not say, "required".	The manipulation represents a violation of the sufficient technique G117
1.4.3 Contrast (Minimum) (AA)	The contrast between headings and background was 4.5 : 1 (#007FAF | #FFFFFF); The contrast between text and background was 21.0 : 1 (#FFF | #000000)	*The contrast between headings and background was 3.9 : 1 (#007FEF | #EFFFFF); The contrast between text and background was 4.0 : 1 (#FFFFFF | #7F7F7F)	*The contrast between headings and background was 3.9 : 1 (#007FEF | #EFFFFF); The contrast between text and background was 4.0 : 1 (#FFFFFF | #7F7F7F)	The manipulation represents a violation of the sufficient technique G18. The chosen contrasts seem to be realistic since the screening revealed that there are plenty of websites containing contrasts about 3.0:1 or lower
1.4.4 Resize text (AA)	Text can be resized without assistive technology up to 200 percent without loss of content or functionality	Resizing text to 200 percent caused text passages to be truncated or obscured.	Resizing text to 200 percent caused text passages to be truncated or obscured.	The manipulation is based on common failure F69 (Manipulated for further studies - Did not affect nonimpaired users because nobody resized text)
1.4.8 Visual presentation (AAA)	Text blocks had a maximum width of 80 characters and were left aligned	*Text blocks had a maximum width of 90 characters and were justified	*Text blocks had a maximum width of 90 characters and were justified	The manipulation is based on common failure F88 as well as a violation of sufficient technique C20
2.4.3 Focus order (A)	Focusable components receive focus in an order that preserves meaning and operability	Focusable components receive focus in an order that preserves meaning and operability	**Some fields in the form did not receive focus in a typical order via tabbing (i.e., skips between fields in different sections of the form. Focus moved from the name field to a checkbox above, then to the street address)	The manipulation is based on common failure F44 as well as example 5 of understanding SC 2.4.3

Success criterion (WCAG 2.0 level)	**AA-website**	**A-website**	**NA-website**	**Comments – reference to the document Understanding WCAG 2.0**
2.4.4 Link Purpose (in context) (A)	Links for sending an e-mail to a certain person were presented as mail address (e.g., john.smith@example.com - the purpose can be determined from the link text only)	*Links for sending an e-mail to a certain person were labeled “contact” within the same paragraph as the description of the respective person (the purpose can be determined from the link text together with its context)	**Links for sending an e-mail to a certain person were labeled “link” within the same paragraph as the description of the respective person (the purpose can not be determined with certainty form the link text together with its context)	The manipulation is based on common failure F88 as well as a violation of sufficient technique C20.
2.4.6 Heading and Labels (AA)	Heading and labels describe topic and purpose	*Some headings were shortened to be less descriptive (e.g., from “information about the town Eschen” to “general information”)	*Some headings were shortened to be less descriptive (e.g., from “information about the town Eschen” to “general information”)	The manipulation represents a violation of the sufficient technique G117
2.4.7 Focus visible (AA)	Keyboard focus indicator was visible	*Keyboard focus indicator was not visible	*Keyboard focus indicator was not visible	The manipulation is based on common failure F78
2.4.10 Section Headings (AAA)	Section headings were used to organize the content	*Some section headings were removed	*Some section headings were removed	The manipulation represents a violation of the sufficient technique G141 & H69
3.2.3 Consistent navigation (AA)	Navigational mechanisms occurred in the same relative order	Some navigation links were not presented in the same order on some web pages but only in the HTML file (i.e., remarkable when using a screen reader). The change in position was not visible due to holding the position via CSS.	Some navigation links were not presented in the same order on some web pages but only in the HTML file (i.e., remarkable when using a screen reader). The change in position was not visible due to holding the position via CSS..	Not remarkable without using screen reading software. The manipulation is based on common failure F66
3.4.4 Consistent Identification (AA)	Links are designed consistently bold, in blue color and underlined	*Links differ in design: links were either blue and not underlined or underlined and in the same color as text. Links were also not consistently bold.	*Links differ in design: links were either blue and not underlined or underlined and in the same color as text. Links were also not consistently bold.	The problem frequently occurred in the screening
3.3.1 Error identification (A) & 3.3.3 Error suggestions (AA)	If an input error in the form was automatically detected, the item that was in error was detected and described by the user in text (i.e., the field was marked with a red square and a textual suggestion on how to complete the field)	If an input error in the form was automatically detected, the item that was in error was detected and described by the user in text (i.e., the field was marked with a red square and a textual suggestion on how to complete the field)	**There was no error identification used in the form	The manipulation is based on a violation of sufficient technique G83

Note. Modifications from level AA to level A are highlighted as *. Modifications from level A to NA are highlighted as **. Common failures and sufficient techniques are based on Cooper, Kirkpatrick, & O Connor (2014).

3.6 Study Two: Implementing Recommendations from Web Accessibility Guidelines: A Comparative Study of Nondisabled Users and Users with Visual Impairments

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3.6.1 Abstract

Objective. The present study examined whether implementing recommendations of web accessibility guidelines would have different effects on nonimpaired users than on users with visual impairments.

Background. The predominant approach for making websites accessible for users with disabilities is to apply accessibility guidelines. However, it has been hardly examined whether this approach has side effects for nonimpaired users. A comparison of the effects on both user groups would contribute to a better understanding of possible advantages and drawbacks of applying accessibility guidelines.

Method. Participants from two matched samples, comprising 55 participants with visual impairments and 55 without impairments, took part in a synchronous remote testing of a website. Each participant was randomly assigned to one of three websites, which differed in the level of accessibility (very low, low, and high) according to recommendations of the well-established web content accessibility guidelines 2.0 (WCAG 2.0). Performance (i.e., task completion rate and task completion time) and a range of subjective variables (i.e., perceived usability, positive affect, negative affect, perceived aesthetics, perceived workload and user experience) were measured.

Results. Higher conformance to web accessibility guidelines resulted in increased performance and more positive user ratings (e.g., perceived usability or aesthetics) for both user groups. There was no interaction between user group and accessibility level.

Conclusion. Higher conformance to WCAG 2.0 may result in benefits for nonimpaired users and users with visual impairments alike.

Application. Practitioners may use the present findings as a basis for deciding on whether and how to implement accessibility best.

Keywords. Web accessibility, visual impairments, nonimpaired users, WCAG 2.0

3.6.2 Introduction

In modern society, a large proportion of the population uses the web, but these users differ considerably in their competencies, characteristics, and needs. Therefore, research on website design for specific user groups (e.g., children, older people, inexperienced users) has become an increasingly popular issue in the field of human-computer interaction (e.g., Jacko, 2012). People with disabilities also represent such a specific user group, which is important to consider in website design (e.g., Vu & Proctor, 2011). About one in six persons has some type of disability (WHO, 2011), such as a visual impairment, a hearing impairment or a motor impairment. Such impairments may result in various barriers when using websites. For instance, a person with impaired eyesight may have difficulty reading content on a website because the text-to-background contrast is too low; a person with a hearing impairment cannot access audio information; or a user with a motor impairment cannot access a button on a form because he cannot click it with the mouse. It is obvious that these kinds of barriers lead to disadvantages in a society that relies heavily on web services. Therefore, web content accessibility guidelines aim to reduce barriers for users with disabilities by providing recommendations on disability-friendly website design. These recommendations include appropriate thresholds for text-to-background contrasts or the use of captions for audio content (e.g., Caldwell et al., 2008). Accessibility practitioners as well as researchers endorse the application of such accessibility guidelines, which makes it the prevailing approach in website design for supporting users with disabilities (e.g., Cooper, Kirkpatrick, & O Connor, 2014; Jacko, 2012; Thatcher et al., 2006; Vu & Proctor, 2011; Yesilada et al., 2012).

However, there is some controversy about whether implementing accessibility guidelines may result in negative side effects for nonimpaired users. While practitioners often assume such negative consequences for nonimpaired users (e.g., disability-friendly websites are ugly, dull, or boring; Ellcessor, 2014; Petrie et al., 2004; Thatcher et al., 2006), recent research has shown positive effects of applying accessibility guidelines for nonimpaired users (Schmutz, Sonderegger, & Sauer, 2016). Investigating such side effects is of importance because it is very rare that only people with disabilities use a website. Instead, nonimpaired users usually constitute the vast majority of users. The consequences for nonimpaired users are thus of particular significance for practitioners, not least for economical reasons (e.g., Farrelly, 2011). Since only very few studies have considered effects of implementing accessibility guidelines for nonimpaired users (Yesilada et al., 2013), the present work aims to examine this by comparing the effects of implementing accessibility guidelines for nonimpaired users to users with visual impairments.

3.6.2.1 Web Content Accessibility Guidelines

While several web accessibility guidelines exist (e.g., IBM, 2017; United States Access Board, 2000), the web content accessibility guidelines 2.0 (WCAG 2.0; Caldwell et al., 2008) is the most widely used standard among researchers and practitioners. The WCAG 2.0 is the basis of legal requirements for web accessibility in many countries (e.g., Australia, Canada, Germany, United Kingdom, Switzerland) (Rogers, 2015; Thatcher et al., 2006) and is also the International Organization for Standardisation's yardstick for accessibility (ISO 40500, 2012). The WCAG 2.0 comprises a list of 61 success criteria and enables the classification of a website in one of four accessibility levels: no accessibility (NA), low accessibility (A), high accessibility (AA) and very high accessibility (AAA). Put simply, the more accessibility criteria a website meets, the higher the accessibility level of the website will be (see Caldwell et al., 2008). Although legislation often requires the implementation of WCAG 2.0, it is astonishing that so little is known about possible side effects for nonimpaired users.

3.6.2.2 Effects of WCAG 2.0 on Nonimpaired Users: Research Evidence

Although this study focuses on WCAG 2.0, there are also a few studies that examined the influence of disability-friendly website design on nonimpaired users prior to the release of WCAG 2.0 (e.g., Disability Rights Commission, 2004; Huber & Vitouch, 2008). These studies focused on WCAG 1.0 (c.f., http://www.w3.org/TR/WCAG10/) as the preceding guideline.

Studies based on WCAG 1.0 mainly indicated positive consequences for nonimpaired users, such as shorter task completion time (Disability Rights Commission, 2004), higher perceived usability (Huber & Vitouch, 2008) and higher scores in automated usability testing (Sullivan & Matson, 2000). Since WCAG 1.0 and WCAG 2.0 differ considerably (Reid, 2008; 2009), results from these earlier studies may need to be treated with caution.

To our knowledge, there are only two studies that investigated the effects of WCAG 2.0 on nonimpaired users. In the first study, nonimpaired users tested three versions of a municipal website with different levels of accessibility (NA, A and AA) (Schmutz et al., 2016). Aside from the differences in WCAG 2.0 compliance, the websites contained the same content (e.g., text and images). 61 nonimpaired users solved tasks on the three websites. The results revealed many benefits of the AA website compared to the NA website. This included faster task completion time, higher task completion rate, higher ratings in usability, trust, aesthetics and lower ratings in workload for the AA website. The A website did not differ from the two other websites for any of the variables. In regard to emotional state, the three websites received the same ratings. Although the study used a promising approach by investigating a rather large sample, the sample was quite homogeneous and comprised students only.

The second study used a similar approach but tested nonimpaired users and users with visual impairments (Pascual et al., 2014). Nine users with visual impairments and five nonimpaired users took part in a usability test, assessing two websites presenting tourist information. These websites differed in WCAG 2.0 compliance but contained the same content (i.e., text and pictures). One website corresponded to level NA and the other website to level A. All participants tested both websites by solving a set of tasks. Due to the small sample size, only descriptive results were reported. These results indicated that nonimpaired users showed shorter task completion times when interacting with an A website compared to an NA website. Furthermore, nonimpaired users reported higher satisfaction and more positive affect for the A website than the NA website. Task completion rate did not differ between the websites. Considering the users with visual impairments, the results showed lower task completion time, higher task completion rate and higher satisfaction when using the A website compared to the NA website. They also reported more positive emotion when using the A website. It is to be pointed out that a comparison of effects of disability-friendly website design on nonimpaired users and users with disabilities is of particular interest for practice. Such a comparison allows us to develop a better understanding of advantages and drawbacks of disability-friendly website design for different user groups. Based on this information, practitioners may be able to decide whether WCAG 2.0 should be implemented or not. Pascual et al. (2014) provided important first insights into the effects of WCAG 2.0 on nonimpaired users and people with visual impairments. However, the small sample size and the fact that only descriptive data were reported have to be taken into consideration when interpreting the results. Consequently, future studies should make use of larger samples of nonimpaired users and users with disabilities (e.g., Yesilada et al., 2013).

3.6.2.3 The Present Study

The present work aims to build on previous research by comparing effects of disability-friendly website design on two matched samples of nonimpaired users and users with visual impairments in a controlled quasi-experimental setting. A website's accessibility was manipulated as an independent variable using three WCAG 2.0 levels: NA, A and AA. Each participant solved five standardized tasks on one of the websites. As dependent variables, performance was measured (i.e., task completion time and task completion rate) as well as several subjective measures (i.e., perceived usability, positive and negative affect, aesthetics, workload, and user experience).

Based on previous findings, two hypotheses were formulated. First, higher accessibility levels would lead to higher performance and more positive subjective evaluations for nonimpaired people and people with visual impairments. Second, the advantages of higher accessibility levels were expected to be greater for users with visual impairments than for users without, which would result in a significant interaction between the independent factors accessibility level and user group.

3.6.3 Method

3.6.3.1 Design and Participants

In this experiment, a 2 x 3 between-subjects design was employed, with user group (unimpaired eyesight vs. impaired eyesight) and accessibility level (NA = very low conformance, A = low conformance, AA = high conformance) representing the independent variables.

A total of 110 participants (i.e., N = 55 for each user group) took part in the study. In a first step, participants with visual impairments were recruited in Switzerland, Germany, and Austria. The participants were required to have maximum eyesight of 20% on the better eye, some experience in using the web, and a minimum age of 18 years. Their ages ranged from 22 to 73 years. Of people with impaired eyesight 69% were considered to be blind (i.e., eyesight

< 2% on the better eye) and 31% had reduced eyesight (eyesight between 2% and 20% on the better eye). In a second step, a matched group of 55 users without visual impairments was recruited. These participants were required to have unimpaired acuity (with or without correction) and color vision (i.e., no visual impairment diagnosed by a physician or registered by health insurance). We did not conduct a vision test and relied on self-reported data. Their ages ranged from 22 to 71 years. Matching variables included age, gender, and perceived experience in using the web and computers (combined subjective rating). These variables were statistically tested for possible differences between user groups to reduce the influence of confounding factors. The results showed that there were no differences between the two user groups ($p > .05$ for all three matching variables). Each participant was randomly assigned to one of the website conditions. Table 10 gives an overview of demographic variables as a function of eyesight and website condition. This research complied with the American Psychological Association Code of Ethics and was approved by the Institutional Review Board at the University of Fribourg. Informed consent was obtained from each participant.

Table 10. Matching variables divided into conditions user group and accessibility level

Sample characteristics	I.E.-NA	U.E.-NA	I.E.-A	U.E.-A	I.E.-AA	U.E.-AA	I.E.-Total	U.E.-Total
n	17	17	18	18	20	20	55	55
Women: *n* (%)	8 (47)	5 (29)	13 (72)	12 (67)	8 (40)	10 (50)	29 (53)	27 (49)
Age (*SD*)	42.9 (9.1)	44.5 (15.4)	49.3 (12.3)	43.4 (15.2)	45.4 (15.8)	47 (14.5)	45.9 (12.9)	45.1 (14.8)
Experience (*SD*)	4.4 (0.7)	4.2 (0.5)	3.8 (1.0)	3.5 (0.8)	4.1 (1.0)	3.9 (0.7)	4.1 (1.0)	3.9 (0.7)

Note. I.E. = impaired eyesight; U.E. = unimpaired Eyesight; n = number of participants; web experience: Likert scale from 1 – 5. NA: very low conformance to WCAG 2.0; A: low conformance to WCAG 2.0; AA: high conformance to WCAG 2.0. Experience comprises web and computer experience.

3.6.3.2 The Websites

We created three versions of a municipal website based on existing content (see figure 4). Each version of the website corresponded to a different accessibility level (i.e., NA, A and AA). While only design aspects required in WCAG 2.0 were changed (e.g., contrast and link descriptions), other website characteristics (e.g., text content or pictures) remained the same for the three websites (Schmutz et al., 2016) provide a detailed description of how the websites were made and validated). In total, thirteen criteria were manipulated (see appendix S2a for a complete list of criteria).

The website examined contained information about a municipality in the country of Liechtenstein (Europe). This included for instance information about administrative issues, education, local politics, or leisure services. The design of the website was static (based on HTML and CSS), which means that information was primarily presented by means of text and images, and did not use sound or animations (see Schmutz et al., 2016 for detailed information about the websites).

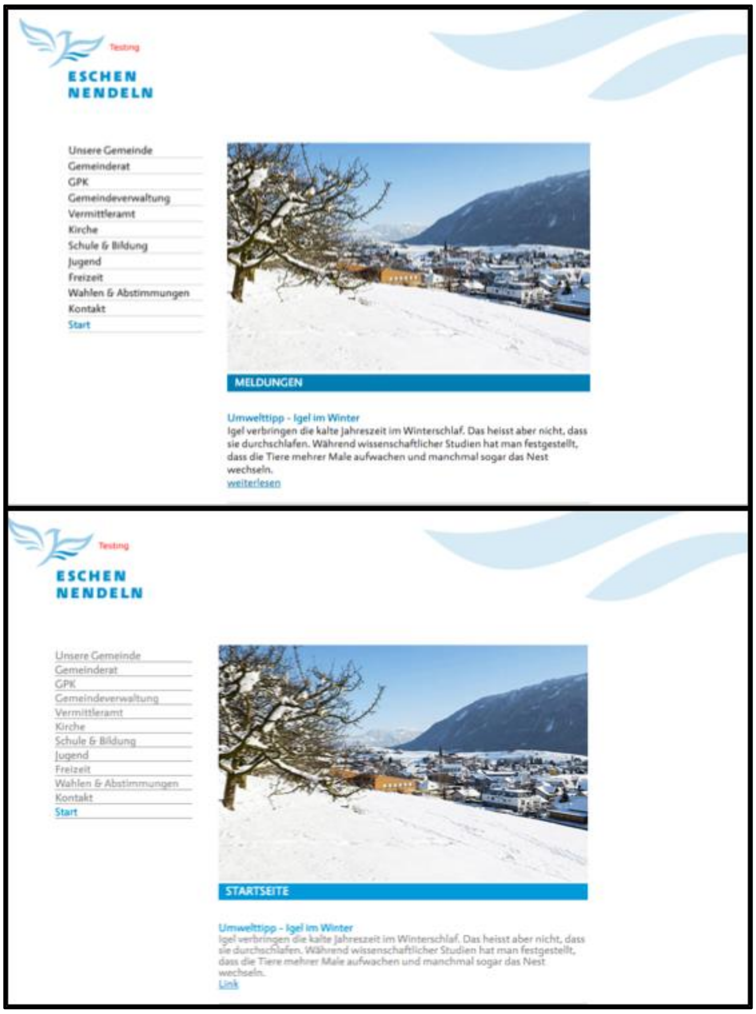

Figure 4. *Screenshots of the home page of the website used for testing (top: level-AA, bottom: level-NA)*

3.6.3.3 Assistive Tools

We asked participants with visual impairments to report the assistive tools they normally use for navigating the website. To increase external validity, we then asked them to use the website the same way. The 55 users with visual impairments used the following assistive tools: a screen reader (14 participants), a screen magnifier (10 participants), a screen reader combined with a braille board (23 participants), and a screen reader combined with a screen magnifier (5 participants). 3 participants used no assistive tool. After the randomized assignment of participants to the three websites, there was no significant difference (p = .425) in the use of assistive tools between these conditions (NA: 17 participants used assistive tools;

A: 17 participants used assistive tools, 1 participant did not use assistive tools; AA: 18 participants used assistive tools, 2 participants did not use assistive tool).

3.6.3.4 Measures

Performance measures. The performance was assessed by measuring task completion rate (%) and task completion time (s). The measurement of task completion time began when the participants started searching the website and ended when they found the information requested. Users without visual impairments marked the appropriate content with the cursor when they found the requested content whereas participants who were visually impaired indicated this orally. If participants did not complete a task within six minutes, they were asked to move on to the next one. In this case, a failed attempt was recorded without explicitly mentioning this to the participants. They were not informed about the time limit to avoid time pressure being induced.

Subjective measures. Six subjective variables were measured: usability, positive and negative affect, aesthetics, workload, and user experience. Theses variables were assessed with German versions of well-established questionnaires. All items were rated on five-point Likert scales. (a) To measure perceived usability the website Analysis and MeasureMent Inventory (WAMMI; Kirakowski, Claridge, & Whitehand, 1998) was used. (b) Positive and negative affect were subjectively evaluated by the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). (c) Perceived aesthetics was assessed by the subscale 'classical aesthetics' of the User Experience Scale (Lavie & Tractinsky, 2004). The scale was chosen for this study because its items make little reference to visual capabilities (e.g., "The website is clean, pleasant or clear" rather than "The colors are appealing"), which made it possible to be used by participants who were visually impaired. (d) Workload was measured by the NASA Task Load Index (NASA TLX; Hart & Staveland, 1988). Since participants were not pressed for time, the item measuring "time pressure" was excluded. This resulted in a 5-item version of the NASA TLX including the dimensions mental demand, physical demand, effort, performance, and frustration. (e) Finally, the User Experience Questionnaire (UEQ; Laugwitz, Held, & Schrepp, 2008) was used to assess user experience. In its original form, the UEQ comprises six subscales (i.e., attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty). Since aesthetics is already assessed by the UES' classical aesthetics scale, the UEQ's subscale attractiveness was not used.

Matching variables. In addition to these dependent measures, we used two items for assessing the matching variable web and computer experience. Web experience was assessed by means of two items (How experienced are you in using computers? How experienced are you in using the web?), using a 5-point Likert scale ranging from 'not at all experienced' to 'very experienced'. According to previous work (e.g., Chadwick-Dias, Tedesco, & Tullis, 2004) the two items about experience were averaged to a single 'web and computer experience score'.

Covariates. Although the two samples (i.e., unimpaired eyesight and impaired eyesight) were matched regarding web and computer experience, age, and gender, the differences of web experience and age between each experimental condition were still considerable. Therefore, age and web experience were used as covariates in all statistical analyses. For the analysis of positive and negative affect, a baseline measure was taken prior to testing and used as an additional covariate. Results of covariates were only reported when they showed a significant relationship with the respective dependent variable.

3.6.3.5 Procedure

We used the synchronous remote testing method in the present experiment. To prepare participants for testing, they received an e-mail explaining the experimental procedure one week prior to the testing session. This e-mail also included a request to install a screen sharing software 'TeamViewer' (www.teamviewer.com), which was required for remote testing (cf. Andreasen, Nielsen, Schrøder, & Stage, 2007; Dray & Siegel, 2004). Prior to the beginning of the testing session participants were contacted by phone. The telephone line was kept open throughout the entire testing session to provide support in case of difficulties. After the introduction by phone, the participants' screen became visible to the experimenter via TeamViewer for the entire testing session. The experimenter also employed TeamViewer's integrated screen recording feature to capture all the interactions of the participants with the website. Participants were then instructed to set two tabs in their browser window, which allowed them to switch easily between questionnaires and test website. Before completing the tasks, participants filled in PANAS as a baseline measure of affect. Afterwards, five tasks were completed (see table 11). When a task had been solved or the time limit of 6 minutes had been exceeded, participants were asked to move on to the next task. After the fifth task, participants completed the PANAS for a second time, followed by the other questionnaires (i.e., WAMMI, NASA TLX, UEQ, Aesthetics and several demographic items).

Table 11. Tasks to be completed on the website

Task	Description
1	Find the e-mail address of the person responsible for education in town.
2	Find the date when the next municipal elections take place.
3	Identify the bus service that will take you to the sports center.
4	Identify the motorway that connects this town with Switzerland.
5	Fill out a form to order firewood from the municipality.

3.6.3.6 Data Analysis

A two-factorial analysis of covariance was conducted with web accessibility (i.e., NA, A and AA) and eyesight (i.e., unimpaired eyesight and impaired eyesight) as fixed factors, together with age and web and computer experience as covariates. All requirements for an ANCOVA were met. For the condition accessibility level, post hoc tests were adjusted using the Bonferroni method and only reported in case of significant differences between groups. To analyze the task completion rate the percentage of successfully completed tasks per participants was used. To analyze the task completion time the mean time per task was used. These performance measures were chosen to match previous work in this field (e.g., Schmutz et al., 2016) to allow comparability of results.

3.6.4 Results

3.6.4.1 Performance Measures

Task completion rate. In line with our prediction, Table 12 shows, that the mean for task completion rate is lowest in the NA condition, followed by A and was found to be highest for AA. The overall effect was significant, $F(2, 102) = 4.12$, $p = .019$, partial-$\eta^2 = .08$. Post hoc tests revealed a significant difference between NA and AA ($p = .027$). The means further indicate that participants with impaired eyesight completed fewer tasks than participant with unimpaired eyesight (see table 12). This difference was also statistically significant, $F(1, 102) = 33.27$, df = 1, 102, $p < .001$, partial-$\eta^2 = .25$. No significant interaction between accessibility level and user group was found ($F(2, 102) = 1.35$, $p = .264$, partial-$\eta^2 = .03$). The covariate age was negatively related to task completion rate, $F(1, 102) = 14.51$, $p < .001$, partial-$\eta^2 = .13$.

Task completion time. According to our expectations, participants showed the highest mean in task completion time when using the NA website, followed by the A website and the lowest task completion time in the AA condition (see table 12). This effect of accessibility level on task completion time was statistically significant, $F(2, 102) = 5.44$, $p = .006$, partial-$\eta^2 = .10$. The post hoc analysis showed that the difference between NA and AA was significant ($p = .007$). The results also indicated that participants with visual impairments were slower than participants without visual impairments (see table 12). This effect of user group on task completion time was also significant, $F(1, 102) = 102.79$, $p < .001$, partial-$\eta^2 = .50$. No interaction between user group and accessibility level was found, $F(2, 102) = 1.06$, $p = .349$, partial-$\eta^2 = .02$. The covariates age, $F(1, 102) = 11.89$, $p = .001$, partial-$\eta^2 = .10$ was positively related to task completion time, while experience, $F(1, 102) = 6.50$, $p = .012$, partial-$\eta^2 = .06$, was negatively related to task completion time.

Table 12. Performance measures as a function of WCAG 2.0 level and user group: means, (standard errors), and [confidence intervals]

Dependent variable	**User group**	**NA**	**A**	**AA**	**Total**
Task completion rate	-	-	-	-	-
-	Impaired eyesight	58.1 (4.5)	60.4 (4.3)	75.4 (4.1)	64.6 (2.5)
-	Confidence interval	[49.1, 67.1]	[51.8, 69.0]	[67.3, 83.5]	[59.7, 69.6]
-	Unimpaired eyesight	83.6 (4.4)	86.3 (4.7)	89.2 (4.1)	86.4 (2.5)
-	Confidence interval	[74.8, 92.4]	[77.4, 95.1]	[81.1, 97.3]	[81.4, 91.3]
-	Total	70.8 (3.2)	73.3 (3.1)	82.3 (2.9)	-
-	Confidence interval	[64.5, 77.2]	[67.1, 79.5]	[76.6, 88.0]	-
Task completion time	-	-	-	-	-
-	Impaired eyesight	260.2 (14.6)	231.3 (14.0)	198.7 (13.2)	230.1 (8.0)
-	Confidence interval	[231.2, 289.1]	[203.7, 259.0]	[172.6, 224.8]	[214.2, 246.0]
-	Unimpaired eyesight	120.4 (14.3)	125.9 (14.4)	95.31 (13.16)	113.9 (8.0)
-	Confidence interval	[92.1, 148.8]	[97.3, 154.4]	[69.2, 121.4]	[98.0, 129.8]
-	Total	190.3 (10.3)	178.6 (10.0)	147.0 (9.3)	-
-	Confidence interval	[169.9, 210.7]	[158.7, 198.5]	[128.6, 165.5]	-

Note. Task completion rate is expressed as a percentage; Task completion time is expressed in seconds. NA: very low conformance to WCAG 2.0; A: low conformance to WCAG 2.0; AA: high conformance to WCAG 2.0.

3.6.4.2 Subjective Measures

Perceived usability. In line with our hypotheses, usability ratings were lowest for the NA condition and highest for the AA condition (see table 13). This main effect of accessibility level on perceived usability was statistically significant, $F(2, 102) = 4.46$, $p = .014$, partial-$\eta^2 = .08$. Post hoc tests confirmed a significant difference between level NA and AA ($p = .012$). No significant main effect of user group was found, $F(1, 102) = 0.39$, $p = .533$, partial-$\eta^2 = .00$ and there was no significant interaction between user group and accessibility level, $F(2, 102) = 0.51$, $p = .598$, partial-$\eta^2 = .08$. The covariate age was negatively associated with perceived usability, $F(1, 101) = 5.53$, $p = .021$, partial-$\eta^2 = .15$.

Positive affect. As presented in table 13, condition NA led to lowest positive affect, whereas condition AA showed the highest positive affect. This corresponds to our assumption. This main effect was statistically significant, $F(2, 101) = 5.70$, $p = .005$, partial-$\eta^2 = .10$. Post hoc tests revealed a significant difference between NA and AA ($p = .005$). There was no main effect of user group on positive affect, $F(1, 101) = 0.71$, $p = .791$, partial-$\eta^2 = .00$, and no significant interaction between user group and accessibility level, $F(2, 101) = 1.08$, $p = .345$, partial-$\eta^2 = .02$.

Negative affect. As the data in table 13 show, there was no significant main effect on negative affect, neither for accessibility level, $F(2, 101) = 1.31$, $p = .268$, partial-$\eta^2 = .03$, nor for user group, $F(1, 101) = 0.35$, $p = .558$, partial-$\eta^2 = .00$. There was also no significant interaction between user group and accessibility level, $F(2, 101) = 1.36$, $p = .261$, partial-$\eta^2 = .03$.

Perceived aesthetics. Confirming our hypothesis, results showed lowest aesthetic ratings for condition NA and the highest ratings for AA (see table 13). This effect of accessibility level was significant, $F(2, 102) = 3.62$, $p = .030$, partial-$\eta^2 = .07$. Post hoc analysis showed a significant difference between condition NA and AA ($p = .029$). No significant effect of user group was found, $F(1, 102) = 0.26$, $p = .873$, partial-$\eta^2 = .00$, and no interaction between user group and accessibility level occurred, $F(1, 102) = 2.03$, $p = .137$, partial-$\eta^2 = .04$.

Perceived workload. The analysis revealed the lowest ratings of workload in the AA condition whereas ratings in the A and NA conditions were higher (see table 13). This main effect of accessibility level was significant, $F(2, 102) = 3.22$, $p = .044$, partial-$\eta^2 = .06$. However, the post hoc analysis did not confirm any significant differences between any of the three conditions (all $p > .05$). In regard to the variable user group, the results showed that participants with impaired eyesight reported higher perceived workload than users with unimpaired eyesight. This effect was also significant, $F(1, 102) = 4.79$, $p = .031$, partial-$\eta^2 = .05$. No interaction between user group and accessibility level occurred for perceived workload, $F(2, 102) = 1.05$, $p = .355$, partial-$\eta^2 = .02$. The covariates age, $F(1, 102) = 8.80$, $p = .004$, partial-η^2 = .08, and web and computer experience, $F(1, 102) = 4.00$, $p = .049$, partial-η^2 = .04, were significantly related to perceived workload.

User experience. Consistent with our hypothesis, condition NA was associated with the lowest and the condition AA with the highest ratings. The overall effect of accessibility level on user experience was significant, F(2, 102) = 3.12, p = .048, partial-η2 = .06. The post hoc analysis demonstrated that level NA and level AA were significantly different (p = .042). Eyesight did not influence ratings of user experience, F(1, 102) = 3.31, p = .072, partial-η2 = .03 and there was no interaction between user group and accessibility level F(2, 102) = 0.15, p = .862, partial-η2 = .00.

Table 13. Subjective measures as a function of WCAG 2.0 level and user group: means, (standard errors), and [confidence intervals]

Dependent variable	**User group**	**Level NA**	**Level A**	**Level AA**	**Total**
Perceived usability	-	-	-	-	-
-	Impaired eyesight	3.1 (0.2)	3.3 (0.2)	3.7 (0.2)	3.4 (0.9)
-	Confidence interval	[2.8, 3.5]	[3.0, 3.6]	[3.4, 4.0]	[3.2, 3.6]
-	Unimpaired eyesight	3.3 (0.2)	3.4 (0.2)	3.6 (0.2)	3.5 (0.9)
-	Confidence interval	[2.9, 3.6]	[3.2, 3.8]	[3.3, 3.9]	[3.3, 3.6]
-	Total	3.2 (0.1)	3.4 (0.1)	3.6 (0.1)	-
-	Confidence interval	[3.0, 3.4]	[3.2, 3.6]	[3.5, 3.8]	-
Positive affect	-	-	-	-	-
-	Impaired eyesight	3.9 (0.1)	4.0 (0.1)	4.3 (0.1)	4.1 (0.1)
-	Confidence interval	[3.7, 4.1]	[3.8, 4.2]	[4.2, 4.5]	[3.9, 4.2]
-	Unimpaired eyesight	4.0 (0.1)	4.1 (0.1)	4.2 (0.1)	4.1 (0.1)
-	Confidence interval	[3.8, 4.2]	[3.9, 4.3]	[4.0, 4.4]	[4.0, 4.2]
-	Total	3.9 (0.1)	4.0 (0.1)	4.3 (0.1)	-
-	Confidence interval	[3.8, 4.1]	[3.9, 4.2]	[4.1, 4.4]	-
Negative affect	-	-	-	-	-
-	Impaired eyesight	1.3 (0.1)	1.5 (0.1)	1.1 (0.1)	1.3 (0.1)
-	Confidence interval	[1.1, 1.6]	[1.3, 1.7]	[0.9, 1.3]	[1.2, 1.4]
-	Unimpaired eyesight	1.4 (0.1)	1.3 (0.1)	1.4 (0.1)	1.4 (0.1)
-	Confidence interval	[1.2, 1.7]	[1.1, 1.6]	[1.2, 1.6]	[1.4, 1.5]
-	Total	1.4 (0.1)	1.4 (0.1)	1.3 (0.1)	-
-	Confidence interval	[1.2, 1.6]	[1.3, 1.6]	[1.1, 1.4]	-

Dependent variable	User group	Level NA	Level A	Level AA	Total
Perceived aesthetics	-	-	-	-	-
-	Impaired eyesight	3.1 (0.2)	3.3 (0.2)	3.9 (0.2)	3.4 (0.1)
-	Confidence interval	[2.7, 3.4]	[2.9, 3.6]	[3.5, 4.2]	[3.2, 3.6]
-	Unimpaired eyesight	3.3 (0.2)	3.5 (0.2)	3.5 (0.2)	3.4 (0.1)
-	Confidence interval	[3.0, 3.7]	[3.1, 3.8]	[3.1, 3.8]	[3.2, 3.6]
-	Total	3.2 (0.1)	3.4 (0.1)	3.7 (0.1)	-
-	Confidence interval	[2.9, 3.4]	[3.1, 3.6]	[3.4, 3.9]	-
Perceived workload	-	-	-	-	-
-	Impaired eyesight	2.7 (0.2)	2.8 (0.1)	2.3 (0.1)	2.6 (0.1)
-	Confidence interval	[2.4, 3.0]	[2.6, 3.1]	[2.1, 2.6]	[2.5, 2.8]
-	Unimpaired eyesight	2.4 (0.2)	2.4 (0.2)	2.3 (0.1)	2.4 (0.1)
-	Confidence interval	[2.2, 2.8]	[2.1, 2.7]	[2.0, 2.5]	[2.2, 2.5]
-	Total	2.6 (0.1)	2.6 (0.1)	2.3 (0.1)	-
-	Confidence interval	[2.4, 2.8]	[2.4, 2.8]	[2.1, 2.5]	-
User experience	-	-	-	-	-
-	Impaired eyesight	3.3 (0.2)	3.5 (0.1)	3.7 (0.1)	3.5 (0.1)
-	Confidence interval	[3.1, 3.6]	[3.2, 3.7]	[3.4, 3.9]	[3.3, 3.6]
-	Unimpaired eyesight	3.1 (0.2)	3.3 (0.2)	3.4 (0.1)	3.3 (0.1)
-	Confidence interval	[2.8, 3.3]	[3.0, 3.6]	[3.2, 3.7]	[3.1, 3.4]
-	Total	3.2 (0.1)	3.4 (0.1)	3.6 (0.1)	-
-	Confidence interval	[3.0, 3.4]	[3.2, 3.6]	[3.4, 3.7]	-

Note. All subjective variables were measured by a Likert scale from 1-5. NA: very low conformance to WCAG 2.0; A: low conformance to WCAG 2.0; AA: high conformance to WCAG 2.0.

3.6.5 Discussion

This study compared effects of a website's accessibility level on two matched samples of nonimpaired users and users with visual impairments. The first hypothesis stated that all users (i.e., people with and without visual impairments) would benefit from higher accessibility levels. The second hypothesis stated that users with visual impairments would benefit more from higher accessibility levels than users without impairments. While the results confirmed the first hypothesis, the second hypothesis was rejected.

The findings are in line with previous work that indicated positive effects of WCAG 2.0– compliant website design on users with and without impairments (e.g., Huber & Vitouch, 2008; Pascual et al., 2014; Schmutz et al., 2016). For all performance and subjective variables (except negative affect), there was a significant main effect of accessibility in the expected direction. This confirms the effectiveness of WCAG 2.0 in improving user performance and users' subjective experience. More surprising was that there was no interaction between accessibility and user group. This suggests that nonimpaired users and users with visual impairments profited from higher accessibility to the same extent. This was unexpected because the main objective of accessibility guidelines is to support users with disabilities (Caldwell et al., 2008). A possible explanation for the missing interaction between user group and accessibility may be that the needs of the two user groups are more similar than previously thought. At first sight, users with visual impairments (especially people who are blind) seem to be different from nonimpaired users in terms of navigation behavior (Takagi, Saito, Fukuda, Asakawa, 2007; Power et al., 2013), mental models (Baumgartner et al., 2010) and general perception (Chiang et al., 2005; Vu & Proctor, 2011). However, this does not necessarily imply that the underlying needs of the two user groups are different. Several authors have emphasized the overlap between design requirements for users with and without disabilities (e.g., Huber & Vitouch, 2008; Mbipom & Harper, 2011; Petrie et al., 2004; Thatcher et al., 2006). Similarly, there have been suggestions that there is considerable overlap between WCAG 2.0 criteria and usability recommendations on website design for nonimpaired users (e.g., Farkas & Farkas, 2000; Nielsen et al., 2002; Shneiderman, 2010; Spool, 1999; Spyridakis, 2000; Williams, 2000). The present work provides first empirical evidence in support of these considerations.

Considering the main effect of accessibility on the dependent variables, it is to note that for most of the variables the post hoc analyses revealed a significant difference between condition NA and AA but not between any of the other conditions. This pattern implies that WCAG 2.0 level AA is to be aimed for when designing a website. Given that the criteria manipulated in the present study are very concrete and easy to implement (see appendix S2a), practitioners can improve the usability of websites for a wide range of users with little effort. Implementing the criteria may have considerable effects because the effect sizes found in the present study were substantial. For example, the improvement of the website from NA to AA increased task completion rate of 11.5% (i.e., about one out of ten tasks is solved or not depending on a website's accordance to WCAG 2.0). This result is to be interpreted by taking into consideration the tasks that the participants had to solve. Even participants without impairments showed an imperfect completion rate (mean = 86.4%). Especially task 1 and 4 were often not completed (i.e., 76% of all incomplete attempts), which might be due to the necessity of clicking several links (task 1) and of screening longer text passages to find the correct answer (task 4). Although we aimed to choose representative tasks for this particular type of website (i.e., municipality), it does not rule out the possibility that the findings could have been different (e.g., task completion rate) if an alternative set of tasks had been employed. Similarly, for task completion time, the changes from NA to A resulted in a decrease in the average task completion time of 43s (22.7%), which is also a substantial reduction given that users leave a page on average after 10 – 20 seconds (Liu, White, & Dumais, 2010). Finally, the subjective measures also consistently showed medium to high effect sizes and confirmed level AA as the standard to strive for. Furthermore, it is to be considered that most of the participants (i.e., 76%) with visual impairments were using assistive tools such as a screen reader (25%) a braille board (42%) or a screen magnifier (9%) because their eyesight was really poor. As pointed out in previous work, the interaction of such users with the web is "..conceptually most different from that of nonimpaired, sighted users" (Petrie & Kheir, 2007, p. 405). We can therefore assume that effects of accessibility on people with other types of disabilities (e.g., hearing impairment or motor impairment) would be even more similar to nonimpaired users.

Overall, the present results are in line with previous findings. Due to the very small number of studies in the field, further research is needed to see whether these findings can be corroborated.

3.6.5.1 Limitations and Future Research

There are a few limitations to consider in regard to the present work. Since the websites used in the study were mainly static, complex dynamic features (e.g., animations, maps, changing text, sounds, etc.) were not addressed. As the disability-friendly design of such features may result in different consequences for nonimpaired users, future research should examine more complex and dynamic websites.

This study focused on a comparison of nonimpaired users with users with visual impairments. Future research should also examine other types of impairments (e.g., hearing, cognitive or motor impairments). Especially knowing more about similarities between user groups might lead to inclusive design solutions that could support different user groups at the same time. Furthermore, this work shows that visual impairment comes in many forms, lies on a continuum (i.e., it is not a dichotomous variable), and may or may not lead to reading difficulties. Such heterogeneity in samples of people with impairments is an issue, which future research needs to address.

Although we present important first evidence on the effects of disability-friendly website design on different user groups, the present study is only a first contribution to an emerging field. As in any other study, there are many possible factors that may have influenced the results. First, recruiting people with visual impairments is of great difficulty. Therefore, previous studies conducting experiments with people with visual impairments tested a rather small number of participants, such as N = 9 (Pascual et al., 2014) or N = 3 (Rømen & Svanæs, 2012). Although we tested a comparatively large sample of people with visual impairments (i.e., 55), the sample is still rather small for computing statistical interactions between independent factors. Future research may aim to examine even larger samples to increase statistical power. Second, in experiments, the kind and strength of manipulation has an influence on the pattern of results found. Future research may aim to replicate present findings by using other stimuli. Furthermore, differences between inaccessible and accessible interfaces should be explored in more detail to identify the elements that caused the effects on performance and subjective evaluations, and their levels of influence.

3.6.5.2 Implications for Practitioners

The present results have important implications for practitioners. Up to now, practitioners have mainly considered the WCAG 2.0 as a tool for supporting users with disabilities (e.g., Caldwell et al., 2008; Ruth-Janneck, 2011). They thus tended to omit its recommendations because: "..there are too many instances where the audience is specifically not those with a disability" (Farrelly, 2011, p. 227). However, the present findings suggest that applying the WCAG 2.0 will benefit users with and without visual impairments alike. If practitioners use WCAG 2.0 as a tool for designing user-friendly websites for both user groups, this is likely to result in market benefits since the needs of a wider range of users are met.

3.6.5.3 Conclusion

In contrast to the general assumption that WCAG 2.0 is an instrument for supporting users with disabilities only, the present results showed that WCAG 2.0 can support users with and without visual impairments alike and should also be recognized as an instrument offering such qualities. We believe that WCAG 2.0 should not be labeled only as a tool that "..will make content accessible to a wider range of people with disabilities.." (Caldwell et al., 2008, p. 1/33) but rather as a tool that makes content user-friendly for people with and without impairments. Emphasizing the advantages of the guidelines for a wide range of users may change the perception of practitioners in a positive way, moving from an "accessibility for users with disabilities"-approach to an "inclusive-design"-approach (e.g., Benyon, Crerar, & Wilkinson, 2001; Clarkson et al., 2013; Newell, & Gregor, 2000). The joint consideration of users with and without disabilities is in our opinion economically promising and morally necessary.

3.6.6 Appendix – Study Two

Appendix S2a. Overview of website characteristics manipulated

Success criterion (WCAG 2.0 level)	**AA-website**	**A-website**	**NA-website**	**Comments – reference to the document Understanding WCAG 2.0**
1.1.1 Non-text content (A)	Every image on the website has an appropriate text alternative	Every image on the website has an appropriate text alternative	For every image, the text alternative “image” was used	The manipulation is based on common failures F30 and F39 (Manipulated for further studies - Did not affect nonimpaired users)
1.3.1 Info and relationships (A)	Required fields in the contact form were labeled with bold text and with an asterisk whose text alternative says, "required".	Required fields in the contact form were labeled with bold text and with an asterisk whose text alternative says, "required".	**Required fields were labeled only with bold text, whose text alternative did not say, "required".	The manipulation represents a violation of the sufficient technique G117
1.4.3 Contrast (Minimum) (AA)	The contrast between headings and background was 4.5 : 1 (#007FAF | #FFFFFF); The contrast between text and background was 21.0 : 1 (#FFF | #000000)	*The contrast between headings and background was 3.9 : 1 (#007FEF | #EFFFFF); The contrast between text and background was 4.0 : 1 (#FFFFFF | #7F7F7F)	*The contrast between headings and background was 3.9 : 1 (#007FEF | #EFFFFF); The contrast between text and background was 4.0 : 1 (#FFFFFF | #7F7F7F)	The manipulation represents a violation of the sufficient technique G18. The chosen contrasts seem to be realistic since the screening revealed that there are plenty of websites containing contrasts about 3.0:1 or lower
1.4.4 Resize text (AA)	Text can be resized without assistive technology up to 200 percent without loss of content or functionality	Resizing text to 200 percent caused text passages to be truncated or obscured.	Resizing text to 200 percent caused text passages to be truncated or obscured.	The manipulation is based on common failure F69 (Manipulated for further studies - Did not affect nonimpaired users because nobody resized text)
1.4.8 Visual presentation (AAA)	Text blocks had a maximum width of 80 characters and were left aligned	*Text blocks had a maximum width of 90 characters and were justified	*Text blocks had a maximum width of 90 characters and were justified	The manipulation is based on common failure F88 as well as a violation of sufficient technique C20
2.4.3 Focus order (A)	Focusable components receive focus in an order that preserves meaning and operability	Focusable components receive focus in an order that preserves meaning and operability	**Some fields in the form did not receive focus in a typical order via tabbing (i.e., skips between fields in different sections of the form. Focus moved from the name field to a checkbox above, then to the street address)	The manipulation is based on common failure F44 as well as example 5 of understanding SC 2.4.3

Success criterion (WCAG 2.0 level)	AA-website	A-website	NA-website	Comments – reference to the document Understanding WCAG 2.0
2.4.4 Link Purpose (in context) (A)	Links for sending an e-mail to a certain person were presented as mail address (e.g., john.smith@example.com - the purpose can be determined from the link text only)	*Links for sending an e-mail to a certain person were labeled "contact" within the same paragraph as the description of the respective person (the purpose can be determined from the link text together with its context)	**Links for sending an e-mail to a certain person were labeled "link" within the same paragraph as the description of the respective person (the purpose can not be determined with certainty form the link text together with its context)	The manipulation is based on common failure F88 as well as a violation of sufficient technique C20.
2.4.6 Heading and Labels (AA)	Heading and labels describe topic and purpose	*Some headings were shortened to be less descriptive (e.g., from "information about the town Eschen" to "general information")	*Some headings were shortened to be less descriptive (e.g., from "information about the town Eschen" to "general information")	The manipulation represents a violation of the sufficient technique G117
2.4.7 Focus visible (AA)	Keyboard focus indicator was visible	*Keyboard focus indicator was not visible	*Keyboard focus indicator was not visible	The manipulation is based on common failure F78
2.4.10 Section Headings (AAA)	Section headings were used to organize the content	*Some section headings were removed	*Some section headings were removed	The manipulation represents a violation of the sufficient technique G141 & H69
3.2.3 Consistent navigation (AA)	Navigational mechanisms occurred in the same relative order	Some navigation links were not presented in the same order on some web pages but only in the HTML file (i.e., remarkable when using a screen reader). The change in position was not visible due to holding the position via CSS.	Some navigation links were not presented in the same order on some web pages but only in the HTML file (i.e., remarkable when using a screen reader). The change in position was not visible due to holding the position via CSS..	Not remarkable without using screen reading software. The manipulation is based on common failure F66
3.4.4 Consistent Identification (AA)	Links are designed consistently bold, in blue color and underlined	*Links differ in design: links were either blue and not underlined or underlined and in the same color as text. Links were also not consistently bold.	*Links differ in design: links were either blue and not underlined or underlined and in the same color as text. Links were also not consistently bold.	The problem frequently occurred in the screening
3.3.1 Error identification (A) & 3.3.3 Error suggestions (AA)	If an input error in the form was automatically detected, the item that was in error was detected and described by the user in text (i.e., the field was marked with a red square and a textual suggestion on how to complete the field)	If an input error in the form was automatically detected, the item that was in error was detected and described by the user in text (i.e., the field was marked with a red square and a textual suggestion on how to complete the field)	**There was no error identification used in the form	The manipulation is based on a violation of sufficient technique G83

Note. Modifications from level AA to level A are highlighted as *. Modifications from level A to NA are highlighted as **. Common failures and sufficient techniques are based on Cooper, Kirkpatrick, & O Connor (2014).

3.7 Study Three: Effects of Disability-Friendly Website Design on Nondisabled Users: Age and Device as Moderating Factors

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3.7.1 Abstract

This study examined how implementing recommendations from Web accessibility guidelines affects nonimpaired people in different age groups using different technical devices. While the recent research showed positive effects of implementing such recommendations for nonimpaired users, it remains unclear whether such effects would apply to different age groups and kind of devices. A 2x2x2 design was employed with website accessibility (high accessibility vs. very low accessibility), age (younger adults vs. older adults) and type of device (laptop vs. tablet) as independent variables. 110 nonimpaired participants took part in a usability test, in which performance and satisfaction were measured as dependent variables. The results showed that higher accessibility increased task completion rate, task completion time and satisfaction ratings of nonimpaired users. While user age did not have any effects, users showed faster task completion time under high accessibility when using a tablet rather than a laptop. The findings confirmed previous findings, which showed benefits of accessible websites for nonimpaired users. These beneficial effects may now be generalised to a wide age range and across different devices.

Keywords. Web accessibility, nonimpaired users, usability, WCAG 2.0

3.7.2 Introduction

Recommendations from Web accessibility guidelines aim to make websites more accessible to people with disabilities (e.g., Chisholm & Henry, 2005; Henry, 2005). Such accessibility recommendations include high contrasts between text and background (supporting users with impaired eyesight), captions for audio content (supporting users with hearing impairments), and operability via keyboard (supporting users with motor impairments who cannot use a mouse) (e.g., Cooper et al., 2014). Although Web accessibility guidelines focus mainly on users with disabilities, recent research has broadened the scope by examining the possible side effects of accessibility recommendations for nonimpaired users (e.g., Pascual et al., 2014). Side effects for nonimpaired users are of particular importance to practitioners because most of the customers are usually nonimpaired (Farrelly, 2011). The consequences for nonimpaired users are thus crucial when deciding whether to implement accessibility recommendations in practice. This reflected in strong concerns among practitioners about negative consequences for nonimpaired users when implementing accessibility recommendations (e.g., applying the recommendations results in ugly, boring or dull websites) (e.g., Ellcessor, 2014; Thatcher et al., 2006).

Recent empirical work did not support the negative beliefs held by practitioners because it found positive effects of disability-friendly website design for nonimpaired users in terms of performance, aesthetics, and usability (Schmutz, Sonderegger, & Sauer, 2016, 2017a). Since there are only very few studies that focused on effects of making websites compliant with accessibility guidelines, the present work aims to continue this line of research by examining the influence of user age and types of device.

3.7.2.1 Web Accessibility Guidelines

Among the different accessibility guidelines available (e.g., IBM 2017; United States Access Board 2000), there is one set of guidelines that were widely used in research and practice: the web content accessibility guidelines 2.0 (WCAG 2.0; Caldwell et al., 2008). The world wide web consortium (www.w3c.org), an international consortium that provides Web standards, has developed these guidelines. Many countries around the globe have recognised the WCAG 2.0 as a reference for legal requirements in regard to accessibility (e.g., Australia, Canada, Germany, Switzerland, Japan, Hong Kong, United Kingdom) (see Thatcher et al., 2006; www.powermapper.com/blog/government-accessibility-standards/). Furthermore, the International Organisation for Standardisation (ISO) acknowledges the WCAG 2.0 as their standard for accessibility (ISO 40500, 2012). The WCAG 2.0 comprises 61 recommendations for disability-friendly website design. These recommendations include: provide text alternatives for images, do not use colour as the only visual means of conveying information, do not use justified text, and make all functionality of the content operable through a keyboard interface (see Cooper et al., 2014). A website's degree of compliance with the recommendations determines its level of accessibility. Four levels are distinguished: no accessibility (NA), low accessibility (A), high accessibility (AA) and very high accessibility (AAA) (see Caldwell et al., 2008). Hereafter the term "accessibility" is used to refer to the compliance of a website with

Web accessibility guidelines (i.e., WCAG 2.0) and its assignment into one of the accessibility levels (i.e., NA - AAA).

3.7.2.2 Web Accessibility Guidelines and Web Usability Guidelines

In this context, we would like to point out some conceptual overlap between the concepts of accessibility and usability. Examining the design recommendations derived from these two concepts, there is substantial overlap between general recommendations for website design (e.g., Farkas & Farkas, 2000; Nielsen et al., 2002; Shneiderman, 2010; Spool, 1999; Spyridakis, 2000; Williams, 2000) and accessible websites. For examples recommendations found in both fields refer to precise link descriptions, heading structures, consistency in design, and text alignment. However, the WCAG 2.0 also comprises some very specific recommendations that are not found in the usability domain (e.g., providing text alternatives for images, providing visible cursor focus, use meaningful tab orders, or particular thresholds for colour contrasts). Although there seems to be some overlap between recommendations in both fields, very little empirical research has examined possible spillover effects between the domains.

3.7.2.3 Accessibility and Nonimpaired Users

Since only very few studies investigated effects of accessibility on nonimpaired users, research evidence about possible consequences for this user group is scarce (e.g., Schmutz, Sonderegger, & Sauer, 2016; Yesilada et al., 2011; 2013). There is some debate about the role of accessibility for nonimpaired users. The concepts discussed are typically accessibility and usability (e.g., Petrie & Kheir, 2007; Thatcher et al., 2006; Yesilada et al., 2013). Usability is an established concept in the field of human-computer interaction, referring to the "extent to which a product [or website] can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (International Organization for Standardisation, 1998, p. 2). When relating the concept of usability to accessibility, the wording "specified users" is of particular interest. Since the term "specified users" does not explicitly include or exclude certain user groups, usability would include people with impairments who could be described as "specified users". Nevertheless, the definition of usability is subject to an intensive debate (see Tractinsky, 2017 for a comprehensive discussion). Furthermore, among researchers and practitioners, usability is usually related to nonimpaired users (e.g., Petrie & Bevan, 2009; Petrie & Kheir, 2007; Thatcher et al., 2006; Yesilada et al., 2013). The relation of the two concepts is not yet fully clarified and discussed in the literature (e.g., Petrie & Kheir, 2007; Thatcher et al., 2006; Yesilada et al., 2012; 2013).

Some authors argue that the definition of Web accessibility should follow the ISO definition of usability and state that Web accessibility is “the extent to which a product/website can be used by specified users with specified disabilities to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (Petrie & Kheir, 2007, p. 397). Such a perspective implies that Web usability and accessibility are two distinct but still similar concepts, which differ only by the fact that accessibility focuses on users with impairments. Other authors argue that usability is an overriding concept, which includes accessibility (Thatcher, Waddell, & Burks, 2002). According to their view, accessibility issues are a subset of usability issues, which implies that usability problems affect everyone, whereas accessibility problems are only of concern to people with impairments. However, Shneiderman (2000) argues that accessibility is a necessary prerequisite for successful usage. This suggests that accessibility is the overriding concept that encloses usability, which is a perspective contrary to (Thatcher et al., 2003). It is to conclude that there are differing opinions about the relationship between Web accessibility and usability. A consensus about this issue would facilitate communication and cooperation among researchers and practitioners (e.g., Yesilada et al., 2012; 2013). Therefore, empirical research should advance the understanding of both concepts and their relationship to each other.

Although there seems to be a vivid discussion about the overlap between the two concepts, very little empirical research has examined possible spillover effects between the domains. The few empirical studies on this issue showed that nonimpaired users performed better (i.e., lower task completion time and higher task completion rates) (Disability Rights Commission, 2004; Pascual et al., 2014) and gave better subjective ratings (e.g., higher perceived usability, higher perceived aesthetics or lower perceived workload) (Huber & Vitouch, 2008; Schmutz et al., 2016) when using websites with high compliance to accessibility guidelines compared to websites with low compliance. One study even showed that the positive effects of accessibility on performance and subjective evaluations were similar for nonimpaired users and users with visual impairments (Schmutz, Sonderegger and Sauer, 2017a).

While first evidence indicated rather beneficial effects of implementing accessibility for nonimpaired users, it has been argued that some factors may influence the beneficial effects of high WCAG 2.0 compliance on nonimpaired users. These factors include the age of users (i.e., nonimpaired users of old age particularly benefit from disability-friendly website design) or the type of device people use (i.e., nonimpaired users particularly benefit from WCAG 2.0-compliant website design when they use a mobile device) (e.g., Carter & Markel, 2001). These two user groups are of particular importance for the HCI community because of demographic and technical changes, which indicate that the number of older users and the number of mobile devices will strongly increase in the near future (e.g., Jacko, 2012; Vu & Proctor, 2011).

3.7.2.4 Accessibility and Older users

There are at least two reasons why we should assume benefits of disability-friendly website design for older users. First, with increasing age, physical and cognitive functioning may decrease. This includes a decline in visual, auditory and motor abilities as well as a decrease in working memory and memory capacities (e.g., Arch, 2010; Hanson, 2009; Seidel et al., 2009). These impairments may lead to similar needs of older people and people with disabilities (e.g., high contrasts for better visibility or captions for audio content) (e.g., Arch, 2010). Second, older users usually have less experience with using websites than younger users (e.g., Chadwick-Dias et al., 2004). Since the lack of experience among older users is often the cause for problems in using websites (Loos, 2009), accessibility may support such users by providing clear and consistent design (e.g., clear link text for better predictability or error identification in forms). In line with these assumptions, the authors of the WCAG 2.0 have argued that the accessibility recommendations provided by the guidelines would be also helpful for older users (Cooper et al., 2014).

To examine these assumptions, an experiment investigated the effects of two WCAG 2.0 recommendations on older users (Sayago, Camacho, & Blat, 2009). Since WCAG 2.0 recommends meaningful and predictable link text and operability via the keyboard, the experiment tested different link designs and keyboard-based navigation with 11 older users, aged 65–80 years. While older users evaluated meaningful and predictable link texts as very supportive and 'good for old folks' (Sayago et al., 2009), they did not consider operability via keyboard as an important feature because they preferred to use a mouse to navigate websites. These results illustrate that some (though not all) WCAG 2.0 recommendations may support older users. A further study dealt with Web accessibility for older users aged 65–78 years (Petrie, Kamollimsakul, & Power, 2013). As WCAG 2.0 recommends text that is not justified and a line spacing of at least space-and-a-half, the study compared two types of text alignment (justified vs. left aligned) and three levels of line spacing (single, space-and-a-half, and double). The results showed that text alignment and line spacing did not affect performance, but older users preferred space-and-a-half or double spacing to single spacing, which is in line with the WCAG 2.0 recommendations. As in the previous study, these results indicate that some WCAG 2.0 recommendations may be supportive for older users, while others are not. The reason why the recommendations from WCAG 2.0 match well the needs of older users may be due to a considerable similarity between website design guidelines for older users (e.g., Kurniawan & Zaphiris, 2005) and the WCAG 2.0 (see Arch, 2010). Although there is evidence that certain aspects of WCAG 2.0 may support older users, some authors are rather critical of this view and believe that additional criteria are necessary to improve the benefits of WCAG 2.0 for older users (e.g., Affonso de Lara, Watanabe, Santos, & Fortes, 2010; Sayago et al., 2009). Based on the literature reviewed, we conclude that there is little empirical research that has focused on this issue and there are contradictory opinions about the effectiveness of WCAG 2.0 for older users. Therefore, further experimental research with older users is needed.

3.7.2.5 Accessibility and Mobile Device Users

Apart from the older users, the use of mobile devices has also become an important issue for practitioners because the number of users browsing websites with a mobile device has strongly increased over recent years. Recent data have shown that in 2016, users browsed more websites by mobile devices than by desktops (51.3% vs. 48.7%, see http://gs.statcounter.com/press/mobile-and-tablet-internet-usage-exceeds-desktop-for-first-time-worldwide). There may be benefits of WCAG 2.0-compliant website design for mobile device users because there is considerable similarity between designing usable websites for mobile devices and disability-friendly website design (e.g., Sears and Young, 2003; Thatcher et al., 2006). For instance, high contrast between font and background can support a user with a visual impairment but also a user employing a mobile device outdoors in poor lighting conditions (see http://www.w3.org/WAI/bcase/soc for more examples). Accordingly, previous work has shown that there is a significant overlap between guidelines for designing usable mobile websites and the WCAG 2.0 (Chuter and Yesilada, 2009; www.w3.org/WAI/mobile/experiences). There is also an empirical study that supported this view (Yesilada et al., 2011). In this study, 19 experts and 57 non-experts examined four websites with the barrier-walk-through-method (e.g., Brajnik, 2006; Yesilada Brajnik and Harper, 2009). This method is based on a heuristic evaluation to detect accessibility barriers on websites. The participants had to identify possible barriers for two user groups: users with disabilities (i.e., visual impairments, blindness and motor impairment) and mobile device users. Afterwards, the authors compared the results for the two user groups, which showed an overlap of 58%. The authors have concluded that many barriers concern both user groups, but there are also a considerable number of specific ones. The review of the work indicated that researchers seem to agree on possible benefits of disability-friendly website design for mobile device users, but to our knowledge, there is no study that conducted a usability test to examine this issue.

3.7.2.6 The Present Study

The present study extents previous work by considering the influence of user age and device when examining effects of disability-friendly website design on nonimpaired people. A website was manipulated to obtain two levels of compliance with WCAG 2.0: NA and AA. A group of younger and older users tested the websites either with a laptop or a tablet device. The dependent variables task completion time, task completion rate and user satisfaction were measured.

Based on the literature review, we made a number of predictions. First, we predicted benefits of the AA website, as compared to the NA website, for both age groups. Second, we expected the positive effects of the AA website to be of greater magnitude for older users than for younger users, regardless of device. Third, we presumed that the benefits of the AA website would be stronger when using a tablet device than when using a laptop, regardless of user age. Fourth, we assumed that the advantageous effects of the AA website for older users would be greater (compared to younger users) when using a tablet device than when using a laptop.

3.7.3 Method

3.7.3.1 Participants and Design

A total of 110 participants (49.1% women) took part in the study. Participants were not paid for taking part in the experiment, but six psychology students received course credits for their participation. Participants were required to be healthy for their respective age (i.e., no diagnosis of any disease). No medical test was conducted.

In a 2x2x2 between-subjects design, the three independent variables were accessibility, age, and device. To manipulate accessibility according to the WCAG 2.0, two versions of a website were used. While the "no accessibility" (NA) version of the website considered only very few WCAG 2.0 criteria, the "high accessibility" (AA) version of the website shows high compliance with the guidelines. The independent variable age comprised a group of "younger" users, aged from 19 to 30 years (n = 55; *M* = 23,7, *SD* = 2.6), and a group of "older" users, aged 55-82 (n = 55; *M* = 62,3, *SD* = 6). In order to manipulate the device, the testing was conducted either by using a laptop or a tablet. We randomly assigned participants to the conditions accessibility and type of device.

3.7.3.2 The Websites

The websites were based on an existing municipal website of the country of Liechtenstein (Europe). This website contained typical governmental information, such as descriptions of the administrative staff, waste disposal, educational institutions, historical facts, registration, and taxes. The information on the website was presented in text or pictorial form. The website did not contain any video material or elements of advanced user interaction (e.g., interactive maps, drag and drop or sliders). The original website was manipulated according to the criteria of WCAG 2.0. The manipulation resulted in two versions of the same website (NA and AA), which differed solely in their compliance with WCAG 2.0 criteria (see appendix S3a for an overview of the criteria manipulated). Apart from these criteria, no changes were made, which ensured that solely the level of accessibility was manipulated (see figure 5 for screenshots). The design of the website was responsive, which allowed a usage with the tablet. More detailed information about the websites and their validation including a manipulation check may be found in Schmutz, Sonderegger, and Sauer (2016).

3.7.3.3 Materials

For browsing the websites, participants used either a laptop (DELL Latitude E7240, 12”) or a tablet (Samsung Galaxy Tab 2, 7”).

3.7.3.4 Measures

Three dependent variables were measured: task completion rate (%), task completion time (s) and user satisfaction. To measure satisfaction, the participants completed the German-language version of the Website Analysis and MeasureMent Inventory (WAMMI; Kirakowski et al., 1998). This questionnaire contained 20 items (Cronbach’s α = .93) (e.g., “Using this website for the first time is easy") and answers were given on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree".

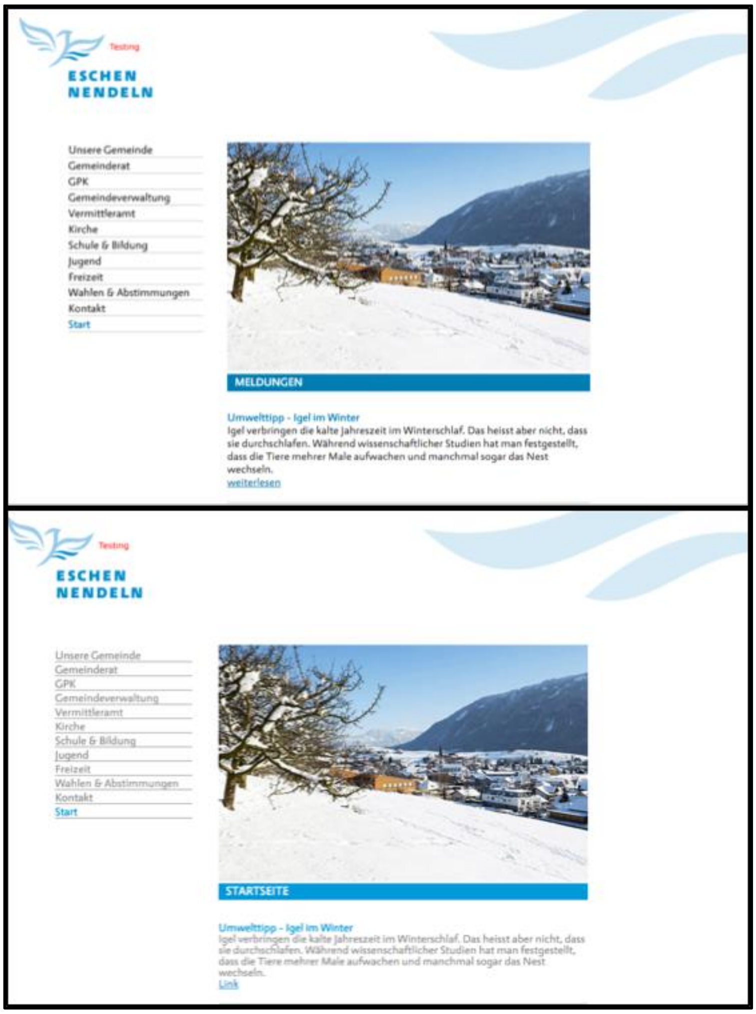

Figure 5. Screenshots of the home page of the website used for testing (top: level-AA, bottom: level-NA)

3.7.3.5 Procedure

The testing sessions were conducted in a quiet room, furnished with a table and a chair. Participants did the testing either by using a laptop or a tablet device. At the beginning of the testing, we instructed participants in the tablet condition how to use a tablet. These instructions comprised touchscreen gestures for clicking, magnifying and scrolling, and information on how to type in text on the tablet. These gestures were demonstrated and practiced on the website of the University of Fribourg. We then briefly showed the municipal website to the participants to ensure that no one had seen the website before. Thereafter, the participants had to complete five tasks (see table 14) either on the laptop or the tablet. Each task had to be completed within 5 minutes. If participants did not complete a task within five minutes, the experimenter asked them to move on to the next task. In such a case, task completion time was set to 5 minutes and task completion was scored as being unsuccessful. A screen recording software logged the testing session, measuring task completion time and task completion rate. After finishing the tasks, every participant filled in the WAMMI questionnaire on the laptop.

Table 14. Tasks to be completed on the website

Task	Description
1	Find the number of people living in this town.
2	Find the motorway that connects this town with Switzerland.
3	Find the e-mail address of the person responsible for education in town.
4	Fill out a form to order firewood from the municipality.
5	Find the bus service that will take you to the sports center.

3.7.3.6 Data Analysis

A three-factorial analysis of variance was conducted with accessibility (NA vs. AA), age (young vs. old) and device (laptop vs. tablet) as independent variables. One video file was lost due to technical problems. The task completion time of this participant was thus not included in the analysis.

3.7.4 Results

3.7.4.1 Task Completion Rate

Table 15 shows the means for task completion rate as a function of accessibility, age, and device. For accessibility, the means indicate that the task completion rate was higher in condition AA (M = 89.1%, SD = 17.9) than in condition NA (M = 81.8%, SD = 19.8). This difference was statistically significant, $F(1, 102) = 4.107$, $p = .045$, partial-$\eta^2 = .039$. In regard to age, the task completion rate was higher for the younger participants (M = 90.4%, SD = 15.3) than for the older participants (M = 80.6%, SD = 21.3). This difference was significant too, $F(1, 102) = 10.814$, $p = .001$, partial-$\eta^2 = .096$. Concerning the device, the means showed that the task completion rate was higher in the laptop condition (M = 92.4%, SD = 15,2) than in the tablet condition (M = 78.6%, SD = 21.3). This difference was highly significant, $F(1, 102) = 18.042$, $p < .001$, partial-$\eta^2 = .150$. There was no significant interaction ($F < 1$).

Table 15. Overview of means (and standard deviations) for the outcomemeasures as a function of accessibility, age, and device

Dependent variable	User	NA-Laptop	NA-Tablet	NA-Total	AA-Laptop	AA-Tablet	AA-Total	Total-Laptop	Total-Tablet	Total-Total
Task completion rate	-	-	-	-	-	-	-	-	-	-
-	Total	89.2 (18.1)	75.2 (19.0)	81.8 (19.7)	95.2 (11.5)	82.3 (21.2)	89.1 (17.9)	92.4 (15.2)	78.6 (20.2)	85.5 (19.1)
-	Young	96.9 (11.1)	81.3 (16.0)	88.6 (15.8)	98.5 (5.6)	86.4 (18.2)	92.2 (14.8)	97.7 (8.6)	83.8 (17.0)	90.4 (15.3)
-	Old	81.5 (20.8)	68.6 (20.3)	74.8 (21.2)	92.5 (14.4)	77.5 (24.2)	86.1 (20.3)	87.6 (18.1)	72.7 (22.2)	80.6 (21.3)
Task completion time	-	-	-	-	-	-	-	-	-	-
-	Total	84.3 (33.2)	124.8 (41.1)	106.1 (42.5)	91.7 (49.5)	94.9 (28.4)	93.2 (40.6)	88.3 (42.5)	110.6 (38.5)	99.6 (41.9)
-	Young	69.3 (28.1)	102.3 (32.1)	87.0 (34.2)	57.1 (21.0)	88.5 (27.4)	73.4 (28.9)	63.2 (25.1)	95.7 (30.3)	80.3 (32.1)
-	Old	100.6 (31.6)	148.8 (36.4)	126.6 (41.6)	119.8 (48.4)	102.2 (29.0)	112.3 (41.5)	111.6 (42.5)	127.3 (40.2)	119.2 (41.8)
User satisfaction	-	-	-	-	-	-	-	-	-	-
-	Total:	3.2 (0.69)	3.2 (0.76)	3.2 (0.72)	3.8 (0.62)	3.3 (0.80)	3.6 (0.74)	3.5 (0.71)	3.3 (0.78)	3.4 (0.75)
-	Young:	3.2 (3.4)	3.5 (0.8)	3.4 (0.7)	3.8 (0.7)	3.6 (0.7)	3.7 (0.7)	3.6 (0.7)	3.5 (0.7)	3.5 (0.7)
-	Old:	3.2 (0.7)	2.9 (0.7)	3.1 (0.7)	3.7 (0.6)	3.0 (0.9)	3.4 (0.8)	3.5 (0.7)	3.0 (0.8)	3.3 (0.8)

Note. NA = very low conformance; AA = high conformance. Task completion rate was measured in %, Task completion time in seconds and user satisfaction with a Likert-scale (1 – 5).

3.7.4.2 Task Completion Time

Table 15 provides the results for task completion time as a function of accessibility, age, and device. The means of the accessibility conditions indicate that participants completed tasks faster in the AA than in the NA condition. This difference was statistically significant, $F(1, 101) = 4.345$, $p = .040$, partial-$\eta^2 = .041$. For the variable age, the means revealed that young participants completed tasks faster than older users. This difference was highly significant, $F(1, 101) = 36.334$, $p < .001$, partial-$\eta^2 = .265$. For considering the device, the results indicated that people using a laptop were faster than participants using a tablet. This difference was also highly significant, $F(1, 101) = 13.794$, $p < .01$, partial-$\eta^2 = .120$. Figure 6 shows a significant two-way interaction, which occurred between the level of disability-friendly website design and device, $F(1, 101) = 6.959$, $p = .010$, partial-$\eta^2 = .064$. This interaction indicates that tablet users were faster under AA, while laptop users were not faster in the AA condition. Finally, the three-way interaction between accessibility level, age and device was significant as well, $F(1, 101) = 6.292$, $p = .014$, partial-$\eta^2 = .059$. Figure 7 shows a comparison of the task completion time between the younger and older users as a function of WCAG 2.0 level and device. In case of younger users, higher WCAG 2.0 conformance led to lower task completion times when using a laptop or a tablet device, whereas, for older users, higher WCAG 2.0 conformance lead to lower task completion times when using the tablet but not when using the laptop.

3.7.4.3 User Satisfaction

Users who employed the AA website gave higher satisfaction ratings than users of the NA website (see table 15). This difference was statistically significant, $F(1, 102) = 6.396$, $p = .013$, partial-$\eta^2 = .059$. In regard to user group, the results revealed a significant difference in satisfaction ratings between younger and older users, $F(1, 102) = 4.432$, $p = .038$, partial-$\eta^2 = .042$, showing that younger users gave slightly higher ratings in satisfaction than older users (see table 15). There was a significant two-way interaction between age and device, $F(1, 102)$

= 4.909, p = .029, partial-η^2 = .046 (see figure 4). Whereas older people preferred to use the laptop, the younger users showed similar satisfaction for both devices.

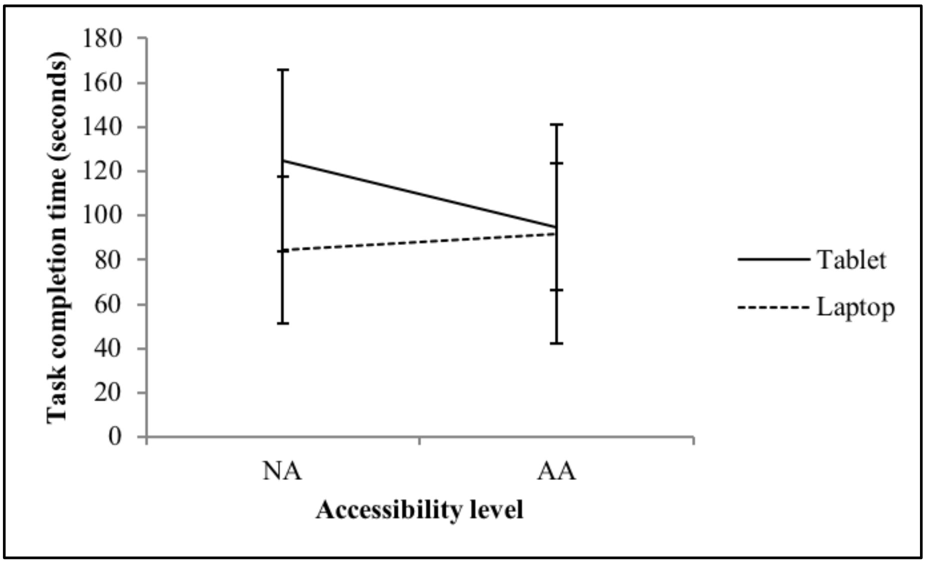

Figure 6. Task completion time as a function of disability-friendly website design level and device (error bars = standard deviation)

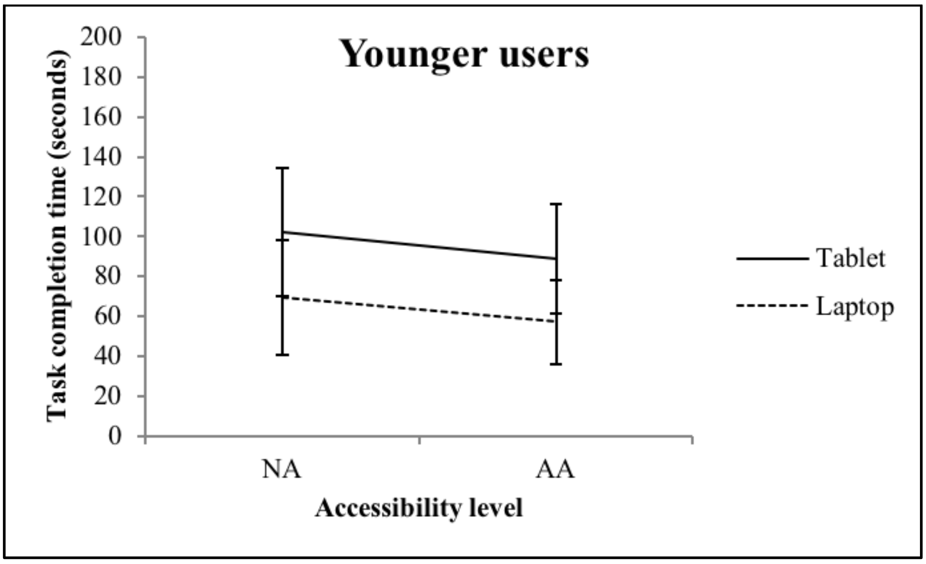

Figure 7a. Task completion time as a function of disability-friendly website design, device and age (error bars = standard deviation)

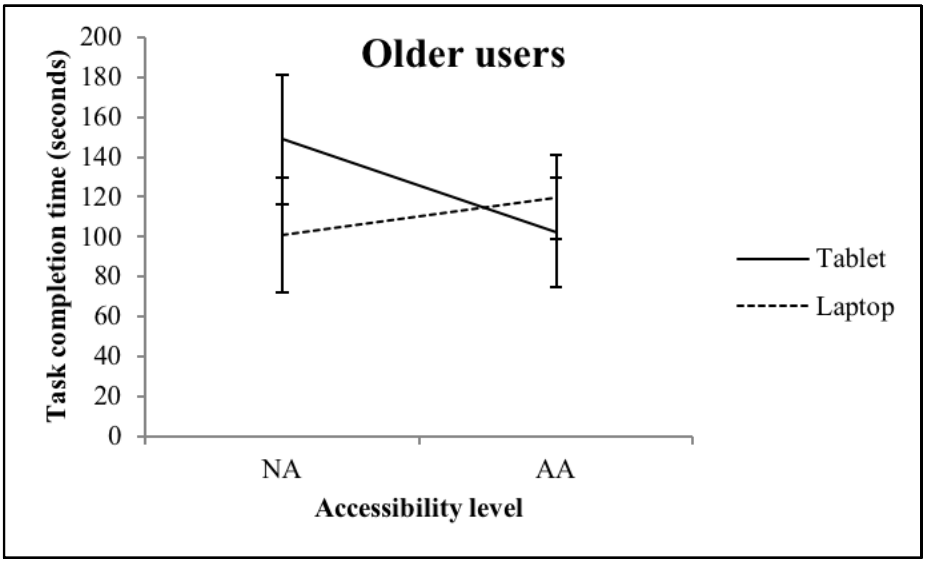

Figure 7b. Task completion time as a function of disability-friendly website design, device and age (error bars = standard deviation)

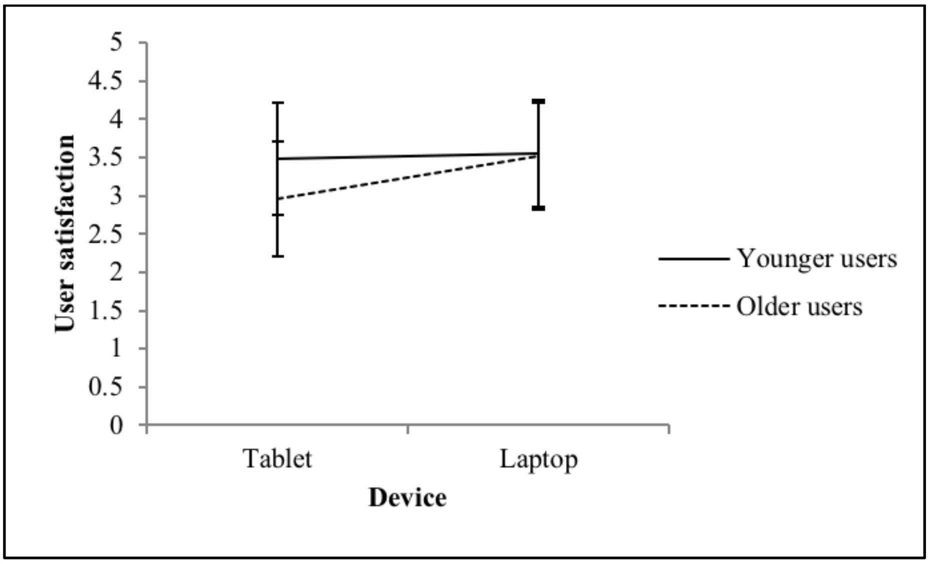

Figure 8. User satisfaction as a function of age and device (error bars = standard deviation)

3.7.5 Discussion

The study aimed to investigate possible effects of WCAG 2.0 recommendations on nonimpaired users as a function of age and the type of device they use. The results partly confirmed our hypotheses by revealing benefits of the AA website, as compared to the NA website, regardless of age and device for each of the three dependent variables. Furthermore, the AA website reduced task completion time compared to the NA website when participants used a tablet but not when they used a laptop. It also emerged that younger users were faster in solving tasks when using the AA website compared to the NA website with both devices, whereas older users only benefitted from the AA website when using the tablet but not with the laptop. Finally, younger users liked the websites more when presented on the tablet rather than the laptop while older users liked the websites more when using the laptop rather than the tablet.

The effects of accessibility on older users are partly in line with previous work dealing with accessibility and older users. AA websites showed benefits for task completion rates, task completion time and user satisfaction for younger and older users alike. This is in accordance with our hypothesis and previous work that showed benefits of WCAG 2.0 recommendations for nonimpaired users (e.g., Huber & Vitouch, 2008). However, against our expectations, participant age did not modify the effect of accessibility for nonimpaired users in the present study. This finding is in line with some previous work that showed that both younger and older users can benefit from certain website characteristics, such as consistent link design, meaningful link texts or structure text with titles (Chadwick-Dias, McNulty, & Tullis, 2003). However, some other work also postulates stronger benefits of disability-friendly website design for older users (e.g., Arch, 2008; Thatcher et al., 2006). We have concluded from the present results that WCAG 2.0 compliant website design may be beneficial for nonimpaired users independent of their age but further research on this issue may be needed.

With regard to the device, the results were in line with our assumptions. People especially benefitted from the AA website when using a tablet rather than a laptop. This finding corresponds to previous work, which found that disability-friendly website design is of particular benefit to users of mobile devices (e.g., Brajnik, 2006; Chuter and Yesilada, 2009; Sears and Young, 2003; Thatcher et al., 2006; Trewin, 2006; Wobbrock, 2006; Yesilada, Brajnik, and Harper, 2009). The positive influence of accessible websites on task completion time was particularly strong for older users employing the mobile device. While younger users solved tasks faster on the AA website (compared to the NA website) with both devices, older users were faster on the AA website when using a tablet but not when using a laptop. It is interesting that older users solved tasks faster on the tablet than on the laptop when using the AA websites, but they still preferred the laptop to the tablet. This may suggest that fast task completion is of less importance for older users. A similar finding emerged in a previous study where younger users were compared to older users in a usability test with mobile phones (Sonderegger, Schmutz, & Sauer, 2016). We have therefore concluded that being able to complete a task quickly does not contribute to product satisfaction for older users.

Considering the conceptual relationship between accessibility and usability (e.g., Petrie & Kheir, 2007; Shneiderman, 2000; Thatcher et al., 2006; Yesilada et al., 2012; 2013), the present results indicate that accessibility and usability seem to be similar concepts. This conclusion is in line with the view of other authors who argued that accessibility and usability have different roots but are overlapping concepts (e.g., Petrie et al., 2004; Petrie & Kheir, 2007).

3.7.5.1 Limitations and Future Research

For this work, we deliberately chose an experimental manipulation of a single website to increase internal validity and control for possible confounding variables. However, by doing so we were not able to investigate different kinds of websites (e.g., social media platforms, online shops or online newspaper), as previous work in the field of accessibility typically did (e.g., Disability Rights Commission, 2004; Petrie et al., 2004). In our opinion, both are valid and important approaches, which should not be considered as contradictory but rather as complementary. Future work on accessibility should thus consider both methodological approaches to advance the field.

We acknowledge that the age groups recruited were dissimilar with regard to the age ranges (i.e., 19 – 30 vs. 55 – 82). Since recruiting older participants for an experiment of considerable size is rather challenging, we decided to accept the difference in the age ranges. Furthermore, it is to point out that there is only a difference of 3.4 years (i.e., 2.6 vs. 6.0) with regard to the standard deviations of the two groups. However, it is possible that the different age ranges may have influenced the results. Furthermore, it has to be acknowledged that the wide range of abilities and experience of the older participants may have influenced the present results. Future studies should thus try to recruit only age groups with the same age ranges. They should also consider possible differences in abilities and experience of older users.

With regard to the effects of device type, the size of the screens (which differed for tablet and laptop) might have also contributed to the present results. Since tablets and laptops (or desktops) typically differ in the size of their screens, we believe that we carried out a realistic comparison of devices. However, future work should consider standardizing screen sizes, which would indicate whether the screen sizes or the kind of navigation (i.e., touch control vs. navigating the cursor with the mouse) is responsible for specific results. Furthermore, future research should expand the present work by examining further devices, such as smart phones and desktops.

3.7.5.2 Implications for Practitioners

This study provides some important implications for practitioners. Implementing WCAG 2.0 recommendations may not only support users with disabilities (i.e., actual purpose of the guidelines), they may also benefit nonimpaired users from young to old age and particularly to mobile device users. Using the WCAG 2.0 as a standard when designing websites seems thus to be a worthwhile approach. This is because the WCAG 2.0 is an effective tool that results in increased user satisfaction across different ages, which offers economical advantages for practitioners.

According to the present results, the WCAG 2.0 seems to be a powerful tool for developers to create websites that meet the needs of a broad range of users. Developers should apply the guidelines when designing websites and should not be overly concerned about possible negative outcomes. The results suggest that user-centred design including user testing should be the method of choice. Such an approach provides helpful insights into the user perspective, which might not always be consistent with the expectations of developers.

For managers, the present results indicate that applying WCAG 2.0 could be a promising business opportunity by offering products or services via accessible websites. Customers with various characteristics could be approached including people with and without disabilities. Furthermore, it may have a positive effect on the image of the organisations because considering needs of people with impairments in products and services would indicate social commitment.

Although several countries already provide legal standards for disability-friendly website design (Thatcher et al., 2006; www.powermapper.com/blog/government-accessibility-standards/, the present results emphasise the importance and feasibility of using disability-friendly website design according to the WCAG 2.0. A strict implementation of the law is advisable because current results indicate that the consequences of doing so are rather positive.

3.7.5.3 Conclusion

The present study examined the effects of implementing accessibility guidelines for nonimpaired users rather than users with disabilities, which is an important issue that has been neglected so far. Furthermore, the study investigated whether the findings can be generalised to nonimpaired users of different ages and when different devices are used. This allows conclusions to be drawn that are relevant to practice because older, as well as mobile device users, represent an important part of contemporary Web users. Considering the present results, we conclude that there may be benefits of disability-friendly website design for laptop and mobile device users of different ages. While the present work builds on previous research on effects of disability-friendly website design on nonimpaired users (Schmutz et al., 2016, 2017a) by being the first that examined effects on older users and mobile device users. Therefore, the present findings make an important contribution that may encourage practitioners to follow Web accessibility guidelines, which may lead to a Web that considers the needs of a wider range of users and thus promotes equality in society.

3.7.6 Appendix – Study Three

Appendix S3a. Overview of website characteristics manipulated

Success criterion (WCAG 2.0 level)	AA-website	A-website	NA-website	Comments – reference to the document Understanding WCAG 2.0
1.1.1 Non-text content (A)	Every image on the website has an appropriate text alternative	Every image on the website has an appropriate text alternative	For every image, the text alternative “image” was used	The manipulation is based on common failures F30 and F39 (Manipulated for further studies - Did not affect nonimpaired users)
1.3.1 Info and relationships (A)	Required fields in the contact form were labeled with bold text and with an asterisk whose text alternative says, "required".	Required fields in the contact form were labeled with bold text and with an asterisk whose text alternative says, "required".	**Required fields were labeled only with bold text, whose text alternative did not say, "required".	The manipulation represents a violation of the sufficient technique G117
1.4.3 Contrast (Minimum) (AA)	The contrast between headings and background was 4.5 : 1 (#007FAF | #FFFFFF); The contrast between text and background was 21.0 : 1 (#FFF | #000000)	*The contrast between headings and background was 3.9 : 1 (#007FEF | #EFFFFF); The contrast between text and background was 4.0 : 1 (#FFFFFF | #7F7F7F)	*The contrast between headings and background was 3.9 : 1 (#007FEF | #EFFFFF); The contrast between text and background was 4.0 : 1 (#FFFFFF | #7F7F7F)	The manipulation represents a violation of the sufficient technique G18. The chosen contrasts seem to be realistic since the screening revealed that there are plenty of websites containing contrasts about 3.0:1 or lower
1.4.4 Resize text (AA)	Text can be resized without assistive technology up to 200 percent without loss of content or functionality	Resizing text to 200 percent caused text passages to be truncated or obscured.	Resizing text to 200 percent caused text passages to be truncated or obscured.	The manipulation is based on common failure F69 (Manipulated for further studies - Did not affect nonimpaired users because nobody resized text)
1.4.8 Visual presentation (AAA)	Text blocks had a maximum width of 80 characters and were left aligned	*Text blocks had a maximum width of 90 characters and were justified	*Text blocks had a maximum width of 90 characters and were justified	The manipulation is based on common failure F88 as well as a violation of sufficient technique C20
2.4.3 Focus order (A)	Focusable components receive focus in an order that preserves meaning and operability	Focusable components receive focus in an order that preserves meaning and operability	**Some fields in the form did not receive focus in a typical order via tabbing (i.e., skips between fields in different sections of the form. Focus moved from the name field to a checkbox above, then to the street address)	The manipulation is based on common failure F44 as well as example 5 of understanding SC 2.4.3

Success criterion (WCAG 2.0 level)	**AA-website**	**A-website**	**NA-website**	**Comments – reference to the document Understanding WCAG 2.0**
2.4.4 Link Purpose (in context) (A)	Links for sending an e-mail to a certain person were presented as mail address (e.g., john.smith@example.com - the purpose can be determined from the link text only)	*Links for sending an e-mail to a certain person were labeled "contact" within the same paragraph as the description of the respective person (the purpose can be determined from the link text together with its context)	**Links for sending an e-mail to a certain person were labeled "link" within the same paragraph as the description of the respective person (the purpose can not be determined with certainty form the link text together with its context)	The manipulation is based on common failure F88 as well as a violation of sufficient technique C20.
2.4.6 Heading and Labels (AA)	Heading and labels describe topic and purpose	*Some headings were shortened to be less descriptive (e.g., from "information about the town Eschen" to "general information")	*Some headings were shortened to be less descriptive (e.g., from "information about the town Eschen" to "general information")	The manipulation represents a violation of the sufficient technique G117
2.4.7 Focus visible (AA)	Keyboard focus indicator was visible	*Keyboard focus indicator was not visible	*Keyboard focus indicator was not visible	The manipulation is based on common failure F78
2.4.10 Section Headings (AAA)	Section headings were used to organize the content	*Some section headings were removed	*Some section headings were removed	The manipulation represents a violation of the sufficient technique G141 & H69
3.2.3 Consistent navigation (AA)	Navigational mechanisms occurred in the same relative order	Some navigation links were not presented in the same order on some web pages but only in the HTML file (i.e., remarkable when using a screen reader). The change in position was not visible due to holding the position via CSS.	Some navigation links were not presented in the same order on some web pages but only in the HTML file (i.e., remarkable when using a screen reader). The change in position was not visible due to holding the position via CSS..	Not remarkable without using screen reading software. The manipulation is based on common failure F66
3.4.4 Consistent Identification (AA)	Links are designed consistently bold, in blue color and underlined	*Links differ in design: links were either blue and not underlined or underlined and in the same color as text. Links were also not consistently bold.	*Links differ in design: links were either blue and not underlined or underlined and in the same color as text. Links were also not consistently bold.	The problem frequently occurred in the screening
3.3.1 Error identification (A) & 3.3.3 Error suggestions (AA)	If an input error in the form was automatically detected, the item that was in error was detected and described by the user in text (i.e., the field was marked with a red square and a textual suggestion on how to complete the field)	If an input error in the form was automatically detected, the item that was in error was detected and described by the user in text (i.e., the field was marked with a red square and a textual suggestion on how to complete the field)	**There was no error identification used in the form	The manipulation is based on a violation of sufficient technique G83

Note. Modifications from level AA to level A are highlighted as *. Modifications from level A to NA are highlighted as **. Common failures and sufficient techniques are based on Cooper, Kirkpatrick, & O Connor (2014).

3.8 Study Four: Easy-to-Read Language in Disability-Friendly Websites: Effects on Nondisabled users

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Because of copyright restrictions, this chapter cannot be published in this thesis. Please consider the official publication by the applied ergonomics journal as soon as the article is published (current reference: Schmutz, S., Sonderegger, A., & Sauer, J. (2017). Easy-to-Read Language in Disability-Friendly Websites: Effects on Nondisabled users. Manuscript accepted for publication with minor revisions in the applied ergonomics journal).

4. General Discussion

The present work aimed to investigate effects of disability-friendly website design on nonimpaired users and users with impairments. We conducted four empirical studies, in which participants used and evaluated websites with different levels of disability-friendly design. While the first three studies focused on disability-friendly website design according to pertinent web content accessibility guidelines (i.e., WCAG 2.0; Caldwell et al., 2008), the fourth study concentrated on the complexity of language as a single criterion of disability-friendly website design.

4.1 Summary and Interpretation of the Main Results

The main results of the present work revealed, first, that disability-friendly website design may provide benefits to nonimpaired users in terms of improved performance and subjective user ratings (study one). Second, that such benefits are similar to the benefits for users with visual impairments (study two). Third, while the type of device can influence the beneficial effect of disability-friendly website design for nonimpaired users, the age of the user does not moderate this effect (study three). Fourth, easy-to-read language, as a criterion of disability-friendly website design, can provide benefits, but also drawbacks concerning performance and subjective user reactions. Table 16 provides an overview of the main effects of disability-friendly website design on the dependent variables measured in the four studies.

Table 16. Overview of the effect sizes (Cohen's d) of the main effects of disability-friendly website design

Variables	**Study 1 (NA vs. AA)**	**Study 2 (NA vs. AA)**	**Study 3 (NA vs. AA)**	**Study 4 (ConvL vs. ETRL)**
Disability-friendly website design on task completion rate	1.22**	0.62*	0.39*	n.s.
Disability-friendly website design on task completion time	-0.99*	-0.73**	-0.31*	n.s.
Disability-friendly website design on perceived usability	0.82**	0.66*	0.40*	n.s.
Disability-friendly website design on perceived aesthetics	0.52*	0.83*	n.m.	n.s.
Disability-friendly website design on perceived trustworthiness	0.57*	n.m.	n.m.	n.s.
Disability-friendly website design on perceived workload	-0.99*	n.s.	n.m.	n.s.
Disability-friendly website design on positive affect	n.s.	0.66**	n.m.	n.s.
Disability-friendly website design on negative affect	n.s.	n.s.	n.m.	n.s.

Variables	Study 1 (NA vs. AA)	Study 2 (NA vs. AA)	Study 3 (NA vs. AA)	Study 4 (ConvL vs. ETRL)
Disability-friendly website design on user experience	n.m.	0.66*	n.m.	n.n.
Disability-friendly website design on reading time	n.m.	n.m.	n.m.	1.24**
Disability-friendly website design on reading speed	n.m.	n.m.	n.m.	n.s.
Disability-friendly website design on free recall	n.m.	n.m.	n.m.	n.s.
Disability-friendly website design on recognition of content	n.m.	n.m.	n.m.	0.44*
Disability-friendly website design on true/false tasks	n.m.	n.m.	n.m.	0.51**
Disability-friendly website design on text liking	n.m.	n.m.	n.m.	-0.86**
Disability-friendly website design on intention to revisit the website	n.m.	n.m.	n.m.	-0.58**
Disability-friendly website design on intention to use the service provided on the website	n.m.	n.m.	n.m.	n.s.
Disability-friendly website design on information retention	n.m.	n.m.	n.m.	n.s.

Note. NA = very low level of disability-friendly website design; AA = high level of disability-friendly website design; * = $p < .05$; ** = $p < .01$, n.s. = not significant, n.m. = not measured, in study one and two the condition A was omitted for the sake of comparability with study three.

Table 16 shows that the patterns of findings were rather homogenous in study one, two and three, but different in study four. While the first three studies showed positive effects on performance in terms of browsing behaviour (i.e., task completion rate and task completion time) and subjective user reactions (e.g., perceived usability and perceived aesthetics), study four did not show any positive effects on these measures. Rather, we found negative consequences of disability-friendly website design on one performance measure (i.e., reading time) and two measures of subjective user reactions (i.e., text liking and intention to revisit the website) in study four. Furthermore, concerning the first three dependent variables in table 16, which are the only variables we consistently measured in all four studies, the pattern of results showed a decrease in effect sizes from large (i.e., $d > 1.22$, study one) to rather small (i.e., $d = 0.39$, study three) and no significant effects in study four.

A plausible explanation for the different pattern of results in the fourth study compared to the other three studies is the manipulation of disability-friendly website design. While in the first three studies we consistently manipulated graphical design aspects (e.g., color contrast, text alignment, and link design), the manipulation in the fourth study was different by focusing only on text complexity. Since these two types of manipulations were quite different, it is not very surprising that the results of study four are not consistent with the patterns in the first three studies.

However, to explain the decrease in effect sizes from the first to the third study is more difficult. A possible reason for this decrease is the age of the participants. While the sample of study one included solely young to middle-aged adults (M = 21.4, SD = 2.4, range = 18 - 35), the samples of the second (M = 45.5, SD = 13.9, range = 22 - 73) and third (total sample: M = 43.0, SD = 19.9, range = 19 – 82; group of young users: M = 23.7, SD = 2.6, range = 19 – 30; group of older users: M = 62.3, SD = 6.0, range = 55 – 82) study were much more heterogeneous concerning age. Age is an important factor in usability testing for several reasons (e.g., Sonderegger et al., 2016). Concerning the variable perceived usability, the attributional style of participants may be important. Based on comments users made during testing, we had the impression that younger and older adults differed in their attributional style. While older adults rather attributed problems in using websites to their own abilities than to the system (e.g., "I often have problems in using websites because older people do not know how this works"), younger users more often attributed problems to the system rather than their abilities (e.g., "This piece of information is difficult to find on this website"). Based on this observation, we could assume that manipulating characteristics of a website would more strongly affect perceived usability ratings of younger adults than of older adults. This is because even if changes in website characteristics would have an effect on the usage by older adults, they would attribute these effects to their own abilities and not the website characteristics. Since we did not systematically assess the attributional styles of the participants, we cannot fully answer this assumption with our data. However, we can analyse the data we have, to get a first idea about possible mechanisms. If the hypothesis about the attributional style is true, correlation coefficients between ratings of perceived performance and perceived usability will be higher in case of younger users than older users. In an earlier study of our research group focusing on usability of smartphones (Sonderegger et al., 2016), we already found such a pattern showing higher correlation coefficients between perceived performance and perceived usability for younger users than for older ones. To conduct this additional analysis, I considered the data of the first three studies by comparing young, middle-aged and older adults (i.e., 18 – 39, 40 – 59 and 60 – 82 years). I created these age groups by dividing the whole range of age (i.e., 18 – 62) into three groups of similar age range. I used the perceived performance item of the NASA-TLX questionnaire (Hart & Staveland, 1988) (i.e., *"How successful were you in accomplishing what you were asked to do?"*) as an indicator of difficulties in using websites. I assume that with more difficulties, lower perceived performance ratings were given. This is not a very precise measure of 'difficulties in using websites' but may be appropriate as a first indicator. As perceived usability measure I used the mean score of the WAMMI questionnaire (Kirakowski et al., 1998). Table 17 provides an overview of the correlations between perceived performance and perceived usability. I separated the results according to the three studies because we did not use the same scaling for perceived performance in all studies (i.e., 1 – 10 vs. 1 – 5).

Table 17. Overview of correlations between perceived performance and perceived usability

Variables	**S1 Young**	**S1 Middle-aged**	**S1 Old**	**S2 Young**	**S2 Middle-aged**	**S2 Old**	**S3 Young**	**S3 Middle-aged**	**S3 Old**
N	61	n.m.	n.m.	40	55	15	55	16	39
Bivariate correlation between perceived performance and perceived usability	.36**	n.m.	n.m.	.44**	.32**	.51$^{n.s.}$	.26$^{n.s}$	.50$^{n.s.}$	.42$^{**.}$

Note. S1 = study 1; S2 = study 2; S3 = study 3; * = *p* < .05; ** = *p* < .01; n.s. = not significant; n.m. = not measured.

The data presented in table 17 do not fully support our assumptions because the correlation coefficients are not consistently lower for older participants compared to younger ones. Therefore, I additionally computed partial correlations between perceived performance and perceived usability with age as a controlled variable to see whether the link between perceived performance and perceived usability still holds when the influence of age is removed. In all three studies the correlation did not notably change when controlling for age (Study 1: bivariate correlation: $r = .36$, $p < .01$, partial correlation: $r = .34$, $p < .01$; Study 2: bivariate correlation: $r = .44$, $p < .01$, partial correlation: $r = .40$, $p < .01$; Study 3: bivariate correlation: .39, $p < .01$, partial correlation: $r = .37$, $p < .01$). The variable age seems to have only a very mall influence on the association between perceived performance and perceived usability. However, since the present data does not fit very well to examine this issue, we cannot fully confirm or refuse the possible explanation concerning age and attributional style. Further data would be necessary to examine the assumption more comprehensively.

In addition to perceived usability, age may also be an important factor concerning the decrease in effect sizes in terms of performance measures. First, it may be that older users are less sensitive to differences in websites than younger ones. This is because younger users might be more experienced in using a wide range of different websites. Therefore younger users might be aware of a larger comparable set of website characteristics. They might thus be more sensitive to small changes (e.g., change in link label, visible focus, tabbing function), which might influence performance. This would imply that older users are generally low in performance and need very salient changes to be affected in behaviour. We can consider our data to -at least roughly- examine this assumption. First, according to this hypothesis, older users should be less experienced in using websites than younger ones. Our data clearly confirms this assumption by showing that older users are significantly less experienced than younger ones. Be it in reported experience in using websites (five-point Likert scale, from not experienced at all to very experienced) or when considering weekly hours of website usage (see table 18).

Table 18. Experience in using websites as a function of age: means and (standard deviations)

Variables	**Young**	**Middle-aged**	**Old**	***F*(df)**	***p***
N	156	71	54	-	-
Perceived experience (1 – 5)	4.0 (0.9)	3.8 (0.8)	3.2 (1.0)	11.33(2)	< .01
Weekly hours of using websites	19.6 (15.6)	13.3 (16.7)	10.3 (15.7)	9.27(2)	< .01

Furthermore, our data should show lower performance values for older than for younger users. Table 19 provides an overview of the performance measures of the first three studies. People had to solve the same tasks on the same website in the first three studies. The data should thus be comparable and were averaged across the three studies.

Table 19. Performance measures as a function of age: means and (standard deviations)

Variables	**Young**	**Middle-aged**	**Old**	***F*(df)**	***p***
N	155	71	53	-	-
Task completion time	113.5 (52.9)	165.4 (83.3)	149.0 (72.0)	17.39(2)	< .01
Task completion rate	82. 2 (18.7)	74.4 (22.5)	74.6 (23.2)	4.88(2)	< .01

Older users generally showed lower performance than younger users. Post-hoc tests revealed that significant differences between old and young users ($p < .01$, two-tailed) for task completion time and task completion rate ($p < .05$, one-tailed). Furthermore, younger users differed significantly from middle-aged users in task completion time ($p < .01$, two-tailed), and task completion rate ($p < .05$, two-tailed). There was no significant difference between older and middle-aged user, neither in task completion time nor task completion rate. These results indicate lower performance for older users than for younger users, which is in line with the hypothesis about the general lower performance of older users. However, these results cannot confirm the assumption about whether older users react less to small changes on websites than younger users. Further data would be necessary to examine this hypothesis comprehensively.

Although current data cannot fully explain the reasons for the patterns of results revealed, the findings of the present thesis are very informative, showing different effects on a wide range of dependent variables. To relate these findings to results of earlier studies can help with integrating present findings into the landscape of web accessibility research.

4.2 Integrating Present Results with Previous Research

For different reasons, it is difficult to relate the present findings to previous work. As far as I know, there is no other study that manipulated WCAG 2.0 conformance or language complexity in a comparable manner. Furthermore, since previous studies considering nonimpaired users usually examined rather small samples and did thus not report inferential statical results (e.g., Disability Rights Commission, 2004; Pascual et al., 2014), statistical comparisons are not possible. However, when considering the little research available, our results are partly in line with other work. While some previous studies also indicated beneficial effects of disability-friendly website design (e.g., Disability Rights Commission, 2004; Huber & Vitouch, 2008) other studies did not find such beneficial effects for nonimpaired users (e.g., Arrue et al., 2007; Pascual et al., 2014). Huber & Vitouch (2008) could show beneficial effects on the perceived usability ratings for nonimpaired users, which we found as well in study one, two and three. The study of the disability rights commission (2004) indicated positive effects on task completion time, which we also found in study one, two and three. However, Arrue et al. (2007) did not find the positive effect on perceived usability ratings, and Pascual et al. (2014) did not find any effect on nonimpaired users, neither in performance nor in ratings of the satisfaction with the website. Karreman et al. (2007) who did consider language complexity as disability-friendly website criterion, did not find any effects with regard to nonimpaired users neither. However, we found positive and negative consequences on nonimpaired users when manipulating language complexity. Findings of previous studies are inconsistent, and our results are in accordance with some of them. Nevertheless, we obtained, at least in the first three studies, a homogeneous pattern showing positive effects of disability-friendly website design according to WCAG 2.0. In addition to a comparison of the findings of the present work with earlier studies, it is important to point out how the four studies conducted contribute to the current state of web accessibility research.

One of the main contributions of our work is the methodological approach used in study one to three. In these studies we emphasised the importance of standardising the content of the test website (i.e., same images, same structure etc.) to reduce confounding factors.

Therefore, compared to earlier studies, our manipulation focused more strongly on disability-design characteristics and brought a new approach of investigating effects of disability-friendly website design to the field. Similar to the first three studies, I argue that the fourth study provides a methodological contribution to the present state of research. To my knowledge, the only other study that investigated effects of easy-to-read language on nonimpaired users did manipulate a website manipulation by adapting language and visual design, such as using bullet points or not (Karreman et al., 2007). Therefore, it is not fully clear whether the results reported in their study were caused by the changes in text complexity or visual design. We thus used in our fourth study a manipulation that focused on the language while the visual design of the website was held constant in both conditions (easy-to-read language vs. conventional language). This minimized again possible distorting factors and allowed us to ascribe our results to the changes in language complexity.

Apart from the methodological contribution, it is also to point out that compared to other work, we examined a considerable number of participants in regard to effects of disability-friendly website design on nonimpaired users. While other work usually tested only a few nonimpaired users (i.e., about 10 participants), our work comprised a total of 354 nonimpaired users (study one: 61, study two: 55, study three: 110, study four: 128). This allowed us to conduct inferential statistical analyses, which were not possible in some of the other work in the field (e.g., Disability Rights Commission, 2004; Pascual et al., 2014).

Finally, it is to emphasize that we contributed to other work by examining a wide range of outcome measures including performance and various subjective user reactions (e.g., task completion rate, task completion time, trustworthiness, affect, workload, aesthetics, text liking). Examining such a wide range of outcome measures contributed to a more comprehensive picture of effects on nonimpaired users when applying disability-friendly website design. This contributes to the current state of research by providing further knowledge about the relation of disability-friendly website design to other variables typically measured in the field of HCI. To investigate such relations is important to clarify HCI processes comprehensively and is also emphasised by various authors (e.g., Ellcessor, 2014; Power et al., 2012; Yesilada et al., 2013). Obviously, for practitioners, it is also very helpful to know the effects of disability-friendly website design on nonimpaired users in terms of a wide range of outcome measures. This helps practitioners in predicting possible consequences when they decide to apply disability-friendly design to websites. It is to conclude that with the present work we addressed many of the main issues of the current state of research, which we described in the introduction (see section 2.4). However, the present work did not only provide several contributions to the current state of research, but its results also provide various implications for practitioners and researchers.

4.3 Implications for Practitioners

A first implication of the present work is that practitioners should not expect uniform consequences of disability-friendly website design, be it in a positive or negative direction. Disability-friendly website design comprises various aspects, which may have, according to the present results, diverse consequences on users. The general concerns that disability-friendly website design has mainly negative consequences for nonimpaired users (e.g., Ellcessor, 2014; Farrelly, 2011; Thatcher et al., 2006) is based on the present findings not empirically supported. Rather, practitioners should consider the specific aspects of disability-friendly website design and the related effects on nonimpaired users. To do this, they should take account of empirical data, such as presented in this work. Although the present findings showed some heterogeneity concerning effects on nonimpaired users, they suggest that practitioners could expect a range of positive consequences for nonimpaired users when implementing WCAG 2.0. Therefore, practitioners should use WCAG 2.0 as kind of a checklist when creating websites to improve the design for users with but also without impairments. Since the study investigating easy-to-read language showed some negative consequences of reduced language complexity, practitioners should be careful when applying this aspect of disability-friendly website design. However, a comprehensive clarification of the main goal of the website and the main target group is necessary. While easy-to-read language showed some detrimental effects on subjective user reactions, there were also positive consequences revealed concerning performance. Practitioners should thus think about these positive and negative consequences for nonimpaired users and how they fit with the main goal of their website. For example, if the main goal is the advertisement of a product or service, the drawbacks of easy-to-read language may be too significant. However, if the main goal of the website is to inform people about complex facts, the positive effects of easy-to-read language may prevail over the negative consequences. To weigh up the various consequences of different aspects of disability-friendly website design, practitioners need as much sound information as possible. Therefore certain limitations of the present work should be considered when interpreting the results and future work should continue to investigate issues related to web accessibility, its components and its consequences for various user groups.

4.4 Limitations and Future Research

While the present work contributed to the present state of research, there are also some limitations to consider. Although our methodological approach offered some advantages compared to procedures in other work, it is to point out that we tested solely two types of websites in our work, namely a governmental website (study one – three) and a website of a leisure centre (study four). Therefore, it is not yet clear whether our results are generalizable to other types of websites (e.g., social networks, news portals, and online shops). It is possible that due to different characteristics of these websites, disability-friendly design may cause different results. When using our websites, participants had mainly to read and search for information. They did not contribute actively with content, such as uploading a picture (e.g., typical for social networks), writing a comment (e.g., typical for news portals) or buy a product (e.g., typical for online shops). It may be possible that disability-friendly design characteristics may influence such activities differently than when acting the way they did in our testing sessions. Therefore, future research should examine effects of disability-friendly website design on nonimpaired user with different types of websites.

Apart from the type of website used, it is to consider that we did mainly studies in a laboratory setting. In study one, three and four participants tested the websites under laboratory conditions. Future work should thus contribute to our work by evaluating whether effects of disability-friendly design on nonimpaired users may be different when using websites in the field (e.g., at home, in the office and outdoors on smart phones). An experimental setting in the lab may differ considerably from "real life" conditions. Therefore, the specific setting may have influenced participants in terms of performance (e.g., because of using not the own computer) or subjective ratings (e.g., social desirability bias (Grimm, 2010). In study two, we did a remote testing with users being at home while communicating with the experimenter via the TeamViewer® software. The results found in this study were comparable to the results found in the other three studies, which indicates that the testing environment may not act as a moderator. However, previous studies of our working group showed that the testing environment may influence user behaviour under certain conditions (Sauer & Sonderegger, 2011). Therefore, future work should deal with this issue by examining effects of disability-friendly website design on nonimpaired users in the field.

A further point to consider is that we conducted summative evaluations of the websites. Summative evaluation implies that a final design is evaluated concerning various outcome measures, such as performance and perceived aesthetics (Gediga, Hamborg, &

Düntsch, 1999; Nielsen, 1993). While this type of evaluation provides information about the quality of a website as a whole, it does not provide information about which specific characteristics of the website users perceived as good or rather bad. To gather such information formative evaluation could be applied in future studies. Formative evaluation is an "evaluation during the development phase in order to improve a system iteratively, until desired design objectives are reached, and weaknesses of the software [website] are eliminated" (Gediga et al., 1999, p. 151). To learn more about effects of disability-friendly website design on nonimpaired users, future studies could conduct formative evaluations with nonimpaired users by testing different websites with different levels of disability-friendly design. This would contribute to the current state of research by clarifying how specific characteristics of websites with disability-friendly design affect nonimpaired users.

Finally, while the present work focused on effects of disability-friendly website design on nonimpaired users, I also argued in the introduction that web accessibility is a complex construct and comprises different components, such as the user, the developer, and the website. Future research could broaden the scope of the present work by not only focusing on one aspect but the construct as a whole. Furthermore, to examine and discuss the position of the construct accessibility within the landscape of HCI research would be a major contribution to the current state of research. This might help to clarify the definition of web accessibility and how it is related to other constructs within the field, such as usability (see Lewis, 2014; Tractinsky, 2017) for a comprehensive discussion of the construct) and UX (see for example (Bargas-Avila & Hornbæk, 2011; Hassenzahl & Tractinsky, 2006; Henry, 2006) for a discussion of the construct), which could facilitate the understanding of the different constructs and the communication among researchers and practitioners (Petrie & Bevan, 2009; Yesilada et al., 2013).

4.5 Conclusion

The main goal of the present work was to investigate effects of disability-friendly website design on nonimpaired users. The results indicated that disability-friendly website design can benefit nonimpaired users in terms of various outcome measures (e.g., performance, perceived usability, perceived aesthetics and perceived workload). Since there is only little research concerned with the topic of disability-friendly website design, further research is needed and of great importance. While the findings of the present work debunked assumptions of practitioners about negative consequences of disability-friendly website design for nonimpaired users, there are also other factors hindering the application of disability-friendly website design in practice, such as a lack of knowledge about the issue or expectations of high costs (Farrelly, 2011). It is thus important to gather further information about the topic to clarify the construct and expectations of web accessibility. The WHO also emphasizes the importance of research in the field of accessibility and states that: "To succeed, accessibility initiatives need to take into account external constraints including affordability, competing priorities, availability of technology and knowledge, and cultural differences. They should also be based on sound scientific evidence." (WHO, 2011, p. 169). I think, with the present work we could contribute important findings to the field, which may advance the current state of knowledge and encourage practitioners to apply disability-friendly website design. Hopefully, in the future, human diversity will become a natural starting point for designing environments, services, and technology, which would make the discussion about effects of accessibility on nonimpaired users superfluous.

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https://www.shareicon.net/repair-tool-outline-wrenches-do-it-yourself-hammer-tools-tool-wrench-tools-and-utensils-outlines-657959

6. Signed Declaration

I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. Except where states otherwise by reference or acknowledgment, the work presented is entirely my own.

Sven Schmutz, Fribourg, 18.10.2017

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