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Why Web Professionals Design for Accessibility: The Importance of User Involvement and Product Quality

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Contents

Abstract

Background. For people with disabilities, the fast development of services on the web and in mobile apps offers great potential for equal participation. Web accessibility enables this potential by preventing the emergence of barriers that result from sensory (e.g., vision, hearing), motor (e.g., tremor, limited use of hands), and cognitive (e.g., learning disabilities, attention deficits) impairments. Taking web accessibility into account extends the usability of web and mobile apps to as many people as possible. Web professionals in various roles – such as interaction designers, visual designers, and developers – define and shape the design of such services and hold a key responsibility for web accessibility. In four manuscripts, we examine the main contributing factors in the adoption of inclusive design practices and explore how those factors can be supported.

Methods and Results. In the first manuscript, we completed a systematic literature review of recently published articles discussing contributing factors in web accessibility adoption, constructed a questionnaire, and conducted a survey of web professionals using the questionnaire. In this process, we identified three key determinants of why web professionals consider web accessibility. First, users with disabilities should have opportunities to offer their perspectives at all stages of the design process. Second, web professionals should integrate web accessibility as a part of their professional role. And third, web accessibility should be perceived as beneficial for the overall quality of a product. The factors of product quality and user involvement were then explored in depth. Product quality was addressed in randomised controlled experiments conducted in the second and third manuscripts. In both studies, the level of accessibility was manipulated to examine its effects on outcomes related to usability and user experience. Manuscript 2 focuses on the question of how reduced language complexity impacts perceived product quality. We found that a combined presentation of text in both conventional and simplified language can provide positive effects for users with cognitive disabilities while not undermining the experience of other user groups. Manuscript 3 focuses on the relation between product quality and compliance with web accessibility standards. The results show that beneficial effects on outcomes related to usability and user experience cannot be expected from compliance with web accessibility standards alone. Finally, the factor of user involvement is explored in the fourth manuscript, in which we detail a case study of a participatory-design approach for involving users with disabilities in the design process.

Conclusion. Designing accessible web and mobile apps is a demanding task. We conclude that (a) involving users with a variety of abilities in the design process is a key component and has an impact on multiple levels. This is closely related to the outcome that (b) web accessibility efforts should go beyond conformance with standards to significantly enhance product quality. Further, the fast-evolving field of web and mobile apps requires (c) strengthening web accessibility at all stages of the design process. Additionally, all professionals involved in the design of inclusive products should (d) expand their personal commitment by establishing an understanding of how inclusion benefits all users and what their individual role can contribute. Based on these findings, we propose implications for research and practice.

Keywords. Disability, Web accessibility, Inclusive design, Web professionals

Introduction

Diversity is part of the richness of life. Over a lifespan, every human being will develop a wide range of abilities, aptitudes, and attitudes (Horton & Quesenbery, 2014). Good design has the power to account for this diversity and to include as many people as possible. This applies equally to the design of web and mobile apps. Their use has become ubiquitous and indispensable for participation in modern society. With this growing importance, designers of web and mobile apps have been entrusted with a key responsibility. By defining and shaping these applications, web professionals in various roles, such as interaction designers, visual designers, and developers, can prevent the emergence of barriers and contribute to opportunities for inclusion (Henry, 2006).

The goal of the present doctoral thesis is to add to the understanding of how web professionals perceive and work on accessible services on the web and in mobile apps. Over the course of four manuscripts, my co-authors and I empirically examine key factors in the adoption of inclusive design practices and explore how those factors can be supported. By gaining insights into contributing factors and their implications, we aim to facilitate work towards more inclusive services that enable participation for as many people as possible.

In the following chapters, we briefly introduce the main theoretical concepts central to this thesis, summarise the core contents of the four manuscripts, and integrate the key findings in the research context. Finally, we discuss implications for research and practice.

Background

Disability

Disability is a multifaceted concept describing human functioning, activities, and participation in a physical and social environment. Over a lifespan, almost everyone will be temporarily or permanently impaired at some point. This makes disability an integral part of the human condition (WHO, 2011). The World Health Organisation (WHO) estimates that about 15% of the population or more than one billion people live with some form of disability (WHO, 2011). The United Nations Convention on the Rights of Persons with Disabilities defines disabilities in people as "long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others" (United Nations General Assembly, 2007, Article 1). This definition synthesises aspects of both the medical and the social models of disability (WHO, 2001). In the *medical model,* a disability is viewed as an individual person's problem caused by a health condition. An individual requires treatment by professionals to cure the condition or to personally adjust to the situation. This contrasts with the *social model*, which focuses on conditions in the social environment of a person. In this perspective, a disability is mainly seen as socially created, which makes it a political issue instead of an individual problem. It requires collective responsibility to provide the environmental modifications necessary for the full participation of people with disabilities in all areas of social life (WHO, 2001).

With their International Classification of Functioning, Disability, and Health (ICF), the WHO proposes integrating the opposing perspectives on disability in a *biopsychosocial* approach (WHO, 2001). **Figure 1** presents a schematic depiction of the described components.

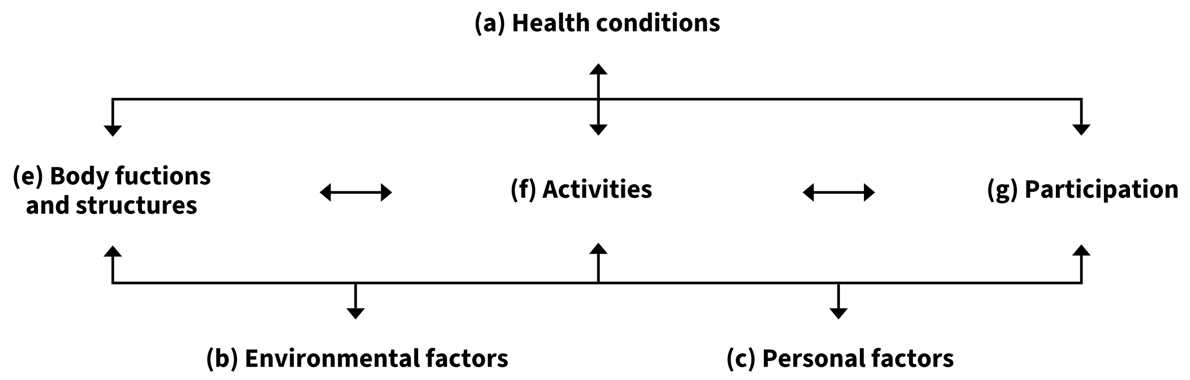

Figure 1. Components of the biopsychosocial approach to disability (adapted from WHO, 2001).

The biopsychosocial approach suggests that disabilities are influenced by three main factors: (a) health conditions, (b) environmental factors, and (c) personal factors. *Health conditions* are an umbrella term for acute or chronic diseases, disorders, injuries, or traumas. *Environmental factors* summarise the context in which a person is acting, including the physical and social environment. *Personal factors* comprise internal resources, such as motivation and self-esteem. These three main factors interact and determine how a disability influences individual functioning. Here, the ICF distinguishes three categories of potential problems: (e) body functions and structures, (f) activities, and (g) participation. *Body functions and structures* focus on physiological functions and anatomical structures, for example, the hearing function as well as the ear and its related structures. *Activities* describe the capacity to execute a task, such as to follow a conversation. *Participation* emphasises involvement in life situations, for example, engaging in a discussion.

The biopsychosocial approach implies that the influencing factors in disabilities can either act as barriers or as facilitators for an individual. For instance, environmental factors also comprise the built environment. Here, a building may have a ramp that enables a person in a wheelchair to enter comfortably, while a flight of stairs may present an insurmountable barrier for the same person.

Importance of Web and Mobile Apps

In recent years, web and mobile apps have become major environmental factors for users with and without disabilities. In this thesis, *web and mobile apps* are defined as interactive applications used in a browser or on a smartphone. This definition includes a large variety of services such as messengers, social media, online shops, and games, among many others. Web and mobile apps have become pervasive and are indispensable in many domains of everyday life, including in daily social, economic, and political participation. As discussed in the previous section, environmental factors can be both facilitators and barriers. This applies to web and mobile apps, which exhibit a large potential to either include or exclude users with disabilities (Ellcessor, 2010). In consequence, accessibility and universal access have been defined as one of the seven major challenges in research on human–computer interaction (Stephanidis et al., 2019).

Technological development has created many opportunities for users with sensory, motor, and cognitive impairments. One example is the growing availability of screen readers on computers and smartphones. A screen reader is a piece of software that reads and describes the graphically presented content and allows blind and visually impaired users to interact with a system. Until the early 2000s, screen readers were capable tools, but they were also expensive and complicated. Today, screen reader software is pre-installed on all major devices and interacting with it has become more intuitive and usable for a broader audience (Kalbag, 2017). However, users with disabilities may also face barriers in their use of web and mobile apps. As presented in **Figure 2**, barriers can arise at multiple points of an interaction. For instance, a user with motor impairments may face a barrier (a) inputting something into a system because of small touch target sizes on an interface. A user with visual impairments may be hindered (b) perceiving the output of a system because it is presented with insufficient colour contrast. Finally, a user with cognitive impairments may have to overcome a barrier in (c) understanding content because it is written in long and convoluted sentences. Such issues substantially limit the potential of web and mobile apps as enablers for equal participation in society (Henry, 2006).

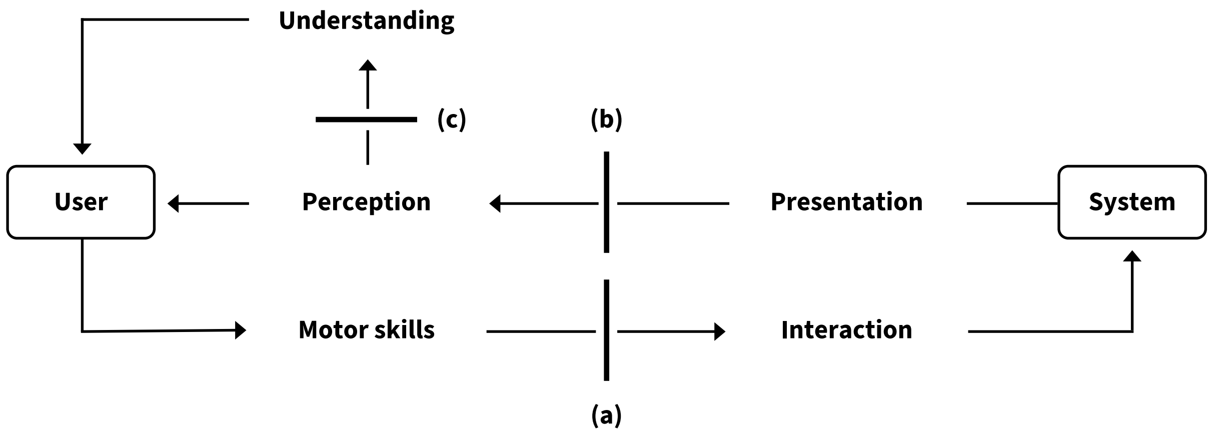

Figure 2. Model of barriers arising during technology use (adapted from Moser & Wieland, n.d.).

Designing for Users with Disabilities

To prevent the emergence of barriers, web and mobile apps must be designed with users with disabilities in mind. Regarding information and services on the web, the term *web accessibility* has been established. In general, web accessibility describes the degree to which a website is usable by as many people as possible (Kalbag, 2017). However, there is not a widely agreed upon definition of the concept among researchers and practitioners (Petrie et al., 2015). A popular definition has been provided by the Web Accessibility Initiative (WAI), a subgroup of the World Wide Web Consortium (W3C). It states that "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" (Yesilada et al., 2012, p. 2). Another often-cited definition has been proposed by the International Standard Organisation (ISO), which defines web accessibility as "the usability of a product, service, environment or facility by people with the widest range of capabilities" (ISO, 2019, Chapter 3.1). Whereas the former definition has a clear focus on people with disabilities, the latter adopts a broader perspective with an extension to all users with different capabilities.

Regardless of the nuances in the definitions, web accessibility must be seen in the context of other concepts (Power et al., 2018). On one hand, in can be placed in the general field of design, which covers digital as well as nondigital products. Here, the ideas of design for all (mainly emerging in Europe; e.g., Bendixen & Benktzon, 2015) and universal design (mainly emerging in the USA; e.g., Iwarsson & Ståhl, 2009) are closely related, as is the concept of inclusive design (e.g., Clarkson et al., 2019), which has a stronger focus on the design process in which a product is created so as to be usable by as many people as possible. All these concepts share an emphasis on the idea of designing artefacts that address the widest audience possible (Sauer et al., 2020). They also integrate the idea that designing for the needs of people with disabilities can serve as an inspiration for designing for the needs of people without disabilities, and vice versa (Pullin, 2011).

On the other hand, in the field of web design, web accessibility overlaps with usability and user experience. Whereas usability focuses on the objective (effectiveness, efficiency) and subjective (satisfaction) outcomes of an interaction in a specific context (ISO, 2019, Chapter 3.13), user experience introduces a holistic view (anticipated and actual use) and a primary focus on emotions (Sauer et al., 2020). Differences and similarities of the concepts have been extensively discussed, and ways to integrate them have been proposed (Aizpurua et al., 2015, 2016; Petrie & Kheir, 2007; Sauer et al., 2020). Further, the close relation of the concepts has also led to questions about how web accessibility affects the usability and user experience of nondisabled users (e.g., Pascual et al., 2014; Schmutz et al., 2016).

Implementation of Web Accessibility

Designing accessible web and mobile apps is a demanding task. It requires a thorough understanding of how individual forms of sensory, motor, and cognitive impairments can be addressed. Various setups for assistive technologies such as screen readers, screen magnifiers, and alternative input mechanisms (Barreto, 2008; Trewin, 2008), which will be handled by users with different skill levels (Vigo & Harper, 2014), must be considered. Appropriate structure and wording must be provided for understandable content (Skaggs, 2016). Further, constantly evolving web and app technologies lead to a large heterogeneity that constitutes a major strength in terms of flexibility and adaptability but can present an obstacle in considering web accessibility (Harper & Chen, 2011). The availability of robust standards as a resource for design decisions is therefore vital for creating accessible web information and services (Henry, 2006). The Web Content Accessibility Guidelines in their second edition (WCAG 2.0) are the most widely applied set of recommendations (Caldwell et al., 2008; for an overview of other standards, see Harper & Yesilada, 2008). WCAG 2.0 is arranged around the four pillars (1) perceivable, (2) operable, (3) understandable, and (4) robust, which are referred to as the POUR principles. The various criteria grouped under these principles are formulated technology agnostic, which make them applicable to interactive technologies beyond web and mobile apps. Today, WCAG 2.0 is the de facto standard for web accessibility with a minor revision (2.2) and a major revision (3.0) in development.

With the web becoming more dominant in everyday life, accessibility has also garnered more public attention. In the policies of several countries, WCAG 2.0 has been referenced as minimal standard for public services (Waddell, 2006). However, despite the availability of WCAG 2.0 since 2008 and its incorporation in legislation, adoption rates remain low. One indicator of the current state of adoption is the WebAIM million, an annual accessibility analysis of the top million home pages on the web (WebAIM, 2022). In March 2022, 96.8% of all home pages had detectable failures, with low contrast text (83.9%), missing alternative text for images (55.4%), empty links (50.1%), and missing form input labels (46.1%) as main issues. A similar result has been reported by Access for all[1], a non-profit organisation based in Switzerland – where the present thesis was written – that publishes a regular analysis of the local state of adoption. Their last report focused on online shops and showed a wide array of issues (Heim et al., 2020), such as missing assistance for interactions, contrast issues, and missing text alternatives. Similar results were found in the last report for the public, educational, and media sector (Bolfing et al., 2016).

Key Role of Web Professionals

Various ideas of how to address this neglect have been discussed, and both top-down and bottom-up approaches have been proposed (Urban & Burks, 2006). *Top-down approaches* include measures such as commitment to a specific web accessibility goal by management, running regular internal or external audits, or organising events to raise awareness of the topic. *Bottom-up approaches*, on the other hand, focus on fostering awareness and knowledge among the members of an enterprise or organisation. The present thesis adopts the latter perspective and focuses on web professionals in various occupational roles working on web accessibility. We define *web professionals* as everyone directly involved in the design process of a product, regardless of whether they are in a technical or a managerial position. Developers and roles that are familiar with user-centred design methods – such as interaction designers, user researchers, and visual designers – are often primarily responsible for considering web accessibility (Vollenwyder et al., 2020). Whereas dedicated accessibility experts appear prominently in

[1] https://www.access-for-all.ch/en

specialised web accessibility surveys (e.g., Yesilada et al., 2014), they are not reported among the top ranks in more broad studies (e.g., Vollenwyder et al., 2020). It is possible that this professional role is still less common in organisations or that they are mainly occupied with promoting general awareness and knowledge and are not directly involved in current projects (Urban & Burks, 2006). Less technical roles, such as product owners, business analysts, and managers, are rarely mentioned as primarily responsible for web accessibility. These roles also tend to be less aware of accessibility issues (Freire et al., 2008; Yesilada et al., 2014).

Multiple attempts to gain more insights about web professionals working in the web accessibility field have been reported in the research. Industry surveys (e.g., Freire et al., 2008; Inal et al., 2020; Yesilada et al., 2012) have provided an overview about work sectors, education, and specialisations. Further, they have covered questions regarding individual definitions of the concept (Yesilada et al., 2012) and the perceived relation of web accessibility to usability and user experience (Yesilada et al., 2014). Other authors have applied content analysis (e.g., De Andrés et al., 2010; Ellcessor, 2014) to explore positive and negative factors influencing the implementation of web accessibility. For example, Ellcessor (2014) focused on the genre of "myth lists" that discuss misconceptions in the industry. This reveals assumptions such as that web accessibility compromises aesthetics and technologically advanced solutions, that it is time-consuming and expensive, or that it only concerns people with visual impairments. Another group of authors have proposed theoretical models for a more comprehensive perspective on the topic (e.g., Farrelly, 2011; Velleman et al., 2017). For instance, Farrelly (2011) outlined an interplay between societal foundations (e.g., education, attitudes towards disability, policies), stakeholder perception (e.g., web professional knowledge, website owner knowledge), tools and resources (e.g., guidelines, support materials, authoring tools), and end users (e.g., user agents, assistive devices).

Aim of This Thesis

Research Questions

As outlined in the previous sections, accessible services on the web and in mobile apps have a great importance for users with disabilities. Web professionals in various roles have a key responsibility in designing such services. However, the relevance of web accessibility contrasts harshly with the actual adoption rate in practice. It is therefore essential to gain a better understanding of the main contributing factors in the adoption of web accessibility and to explore how those factors can be supported.

This thesis aimed to answer three overarching research questions related to why and how web professionals consider web accessibility. The key contributing factors for considering web accessibility were explored and questions surrounding these factors were addressed. For this purpose, we conducted four studies whose results are presented in the form of manuscripts. We addressed the following research questions.

Key Contributing Factors – Manuscript 1

The current research on the topic has discussed a wide range of personal and organisational aspects influencing the adoption of web accessibility. However, a systematic review, validation, and prioritisation of the key factors has been missing. The first research question of this thesis therefore aimed to identify the main influences for adopting web accessibility in practice.

RQ1. *What key factors contribute to why web professionals consider web accessibility?*

In the results regarding the first research question, we identified a set of key contributing factors. Following our research interests, we selected two of these factors and explored related aspects in additional studies.

Product Quality – Manuscripts 2 and 3

The belief that overall product quality can be enhanced through considering web accessibility was addressed in Manuscripts 2 and 3. Manuscript 2 focused on the reduction of language complexity on the web and its impact on perceived product quality. While previous results have shown that all user groups benefit from a better understanding of simplified texts, nondisabled users have expressed a decreased text liking and a reduced intention to revisit a website when it uses simplified texts (Schmutz et al., 2019). We addressed such potential issues by exploring approaches to combine text written in both conventional and reduced language complexity.

RQ2a. *How can reduced language complexity be utilised on the web without undermining how nondisabled users perceive the product quality?*

Manuscript 3 focused on the relation between product quality and conformance to given web accessibility standards. While it is a common practice for web professionals to closely follow web accessibility standards (Holliday, 2020), their alignment with the actual needs of users with disabilities is controversial (e.g., Power et al., 2012). We examined how compliance with web accessibility standards impacts outcomes related to usability and user experience for users with disabilities as well as for nondisabled users.

RQ2b. *How does compliance with web accessibility standards contribute to how users with and without disabilities perceive the product quality?*

User Involvement – Manuscript 4

Users that actively advocate for their specific needs have proved to be another key contributing factor for the adoption of web accessibility by web professionals. Feedback fosters the awareness that there is a demand for accessible services on the web and in mobile apps. Involving users in the design process can actively support the collection of such input and facilitate a better understanding of other perspectives. However, only a few tools and techniques have been developed to capture the subjective experiences of users with disabilities (Power et al., 2018). In a case study detailed in Manuscript 4, we explored participatory design as a potential approach to close this methodological gap in the design of web and mobile apps.

RQ3. *How can the perspective of users with disabilities be included through a participatory design process?*

An overview of the studies is presented in **Figure 3**. All four manuscripts are summarised in the following chapter and can be found as complete manuscripts in the Appendix.

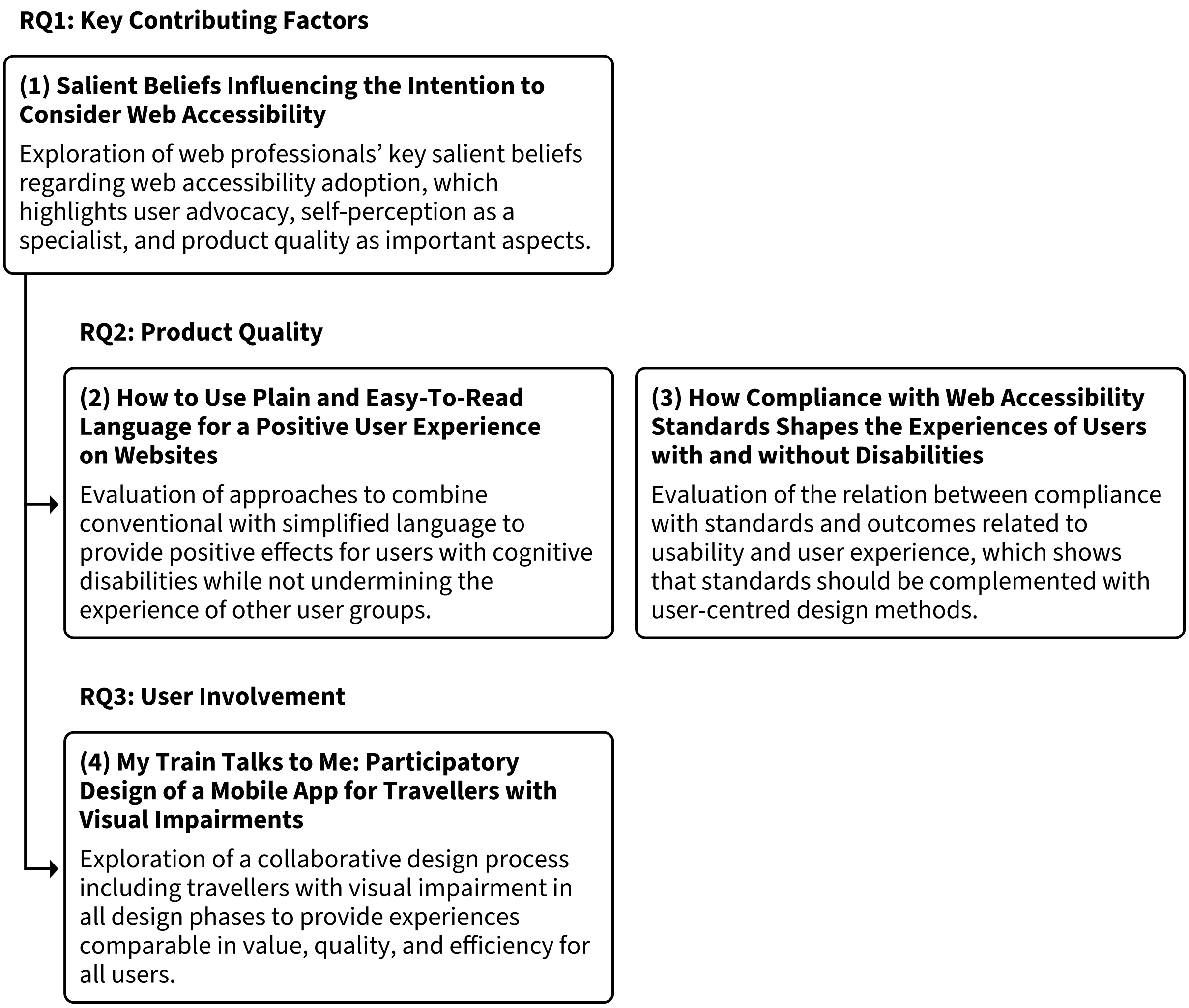

Figure 3. Overview of the manuscripts and their relation to each other.

Summary of the Manuscripts

Manuscript 1 – Salient Beliefs Influencing the Intention to Consider Web Accessibility

Aim of the Study

The rate of adoption of web accessibility standards remains low. A considerable body of research has discussed a wide range of personal and organisational factors that influence adoption. However, it remains unclear to what extent each of these factors shape the intention of web professionals to consider web accessibility in their design process. A better understanding of the drivers and constraints could allow researchers and practitioners to focus their efforts. The aim of the study described in Manuscript 1 was therefore to systematically review the current literature, to identify the most important contributing factors to web accessibility adoption, and to discuss the implications of these findings.

Methods

A multistep approach was used to examine how web professionals form their intention to consider web accessibility in the design process. Based on a systematic literature review including 925 publications and an affinity mapping, twelve often-discussed salient beliefs influencing the intention to consider web accessibility were identified. These beliefs were then integrated in a theoretical model by applying the theory of planned behaviour (Fishbein & Ajzen, 2010). In a next step, we constructed a questionnaire to test the model. To do so, we followed a guide for developing a standard questionnaire to investigate a given model based on the theory of planned behaviour (for details, see Section 3.2 in Manuscript 1). This questionnaire was then used to conduct a survey of web professionals in various occupational roles. A total of 342 web professionals participated in the online study. Finally, a path analysis model was estimated to analyse the most influential salient beliefs.

Results

Inspection of fit indices indicated an unsatisfying fit for the original model, and additional paths based on modification indices were included. This led to an adjusted model that exhibited good values for all fit indices (for details, see Section 4.6.2 in Manuscript 1). The final model with estimated paths is presented in **Figure 4**.

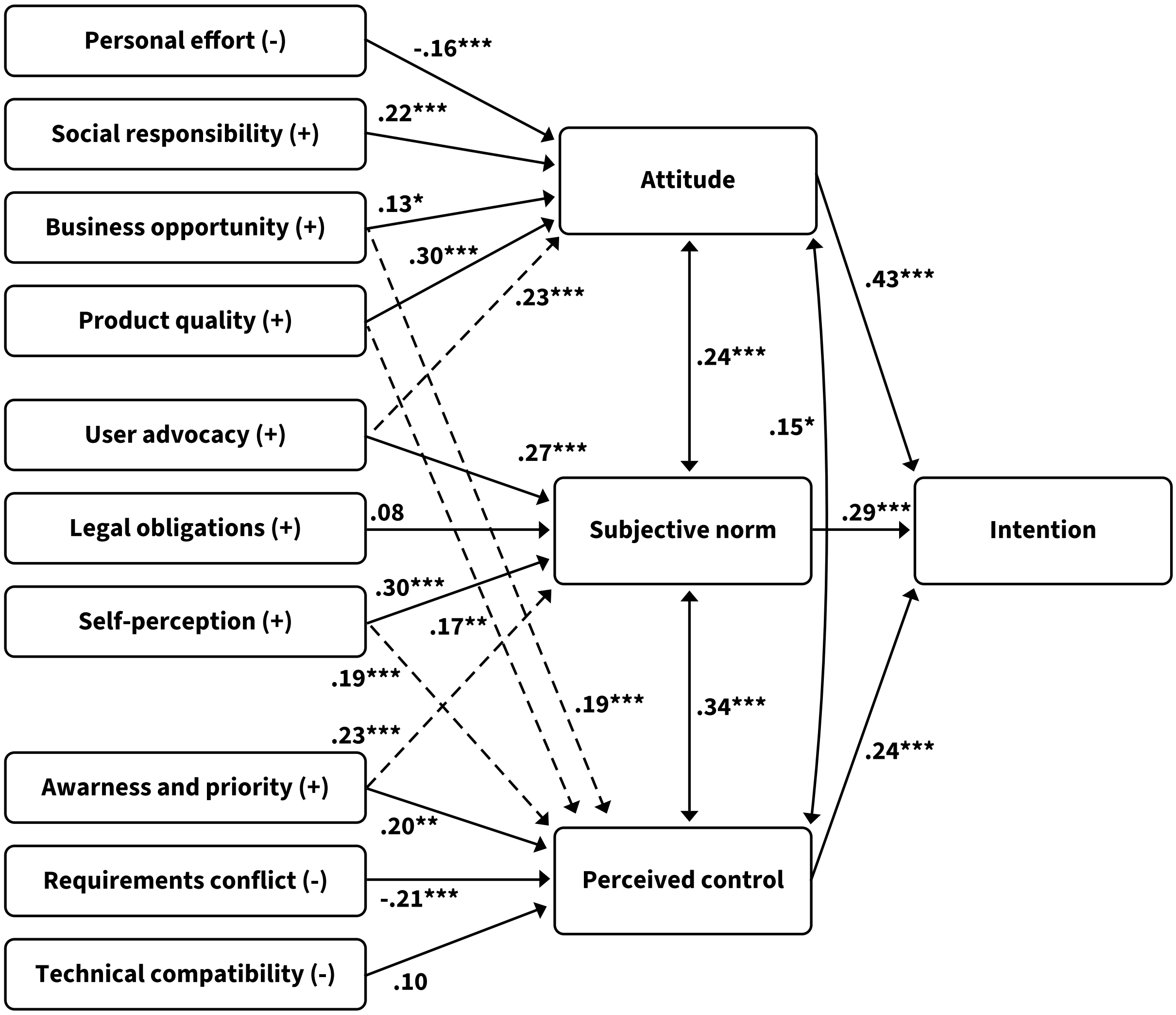

Figure 4. The resulting adjusted model based on the theory of planned behaviour. Plus and minus signs next to the influence factors indicate the expected direction drawn from the literature review. Note: $^{*}p < .05$, $^{**}p < .01$; $^{***}p < .001$

All the paths, except legal obligations on subjective norm and technical compatibility on perceived control were significant. Attitude was found to be the most predictive antecedent for the intention to consider web accessibility. In turn, salient beliefs regarding product quality and user advocacy had the strongest influence on attitude. Subjective norm was found to be mainly influenced by self-perception as a specialist and user advocacy. The most important salient beliefs for perceived control were requirements conflict and awareness and priorities. Overall, the three most favourable salient beliefs observed were: (1) user advocacy, (2) self-perception as a specialist, and (3) product quality. The two most hindering salient beliefs were found to be: (1) requirements conflict and (2) personal effort. Since these limiting factors influenced web professionals' intentions to a lesser extent, we focus the discussion on the driving factors.

Discussion and Conclusion

Based on the resulting model, we identified three key determinants of why web professionals consider web accessibility. First, users should actively advocate for their specific needs and foster an understanding among web professionals that there is a demand for accessible services on the web and in mobile apps. In a design process, this can be facilitated by actively involving users with disabilities, which offers opportunities to bring in various perspectives on a product. Second, web professionals should consider web accessibility as an integral part of their professional roles and see it as their personal responsibility as a specialist. Here, it is important to build up awareness and expertise that can be contributed to accessible products in an individual role. Third, web accessibility should be perceived as beneficial for the overall quality of a product. Promotion of web accessibility as a quality feature for all user groups can strengthen this influence factor. Further, fears regarding unintended side effects of adopting web accessibility should be addressed in research and practice.

Manuscript 2 – How to Use Plain and Easy-To-Read Language for a Positive User Experience on Websites

Aim of the Study

Language complexity is an often-underestimated part of web accessibility. Research and development frequently focus on the perceptibility and operability of web and mobile apps. However, aspects that support understandability, such as content design, structure, and wording, have gained increasing importance in recent years (Miesenberger & Petz, 2014). This has led to the implementation of concepts such as plain language or easy-to-read language. Both approaches aim to reduce language complexity but differ regarding their formalisation and their intended audience. The concept of *plain language* focuses on clear and precise writing that avoids convoluted sentences and jargon. It is centred around readers' goals and tries to make content easily scannable and understandable for as broad an audience as possible (Skaggs, 2016). It contrasts with *easy-to-read language*, which is specifically designed to meet the needs of people with cognitive disabilities (Fajardo et al., 2013). With very clear sentence structures, only one statement per sentence, and the avoidance of difficult words, texts in easy-to-read language attempt to be as simple as possible. While research has reported positive effects of such language simplification for users with cognitive disabilities, unintended side effects on other groups of users have been found (Karreman et al., 2007; Schmutz et al., 2019). Nondisabled users also seem to benefit from improved text understanding, but they prefer conventional language regarding text liking. Further, their intention to revisit a website was reduced when easy-to-read language was applied. Since enhancing the overall quality of a product was shown to be a major influence factor in Manuscript 1, it is important to address such potential issues carefully. The study described in Manuscript 2 therefore explored approaches to combine conventional with easy-to-read language to provide positive effects for users with cognitive disabilities while not undermining the experience of other user groups.

Methods

The study was conducted in collaboration with Swiss Federal Railways (i.e., Schweizer Bundesbahnen, SBB). Based on the experiences of call agents working in the SBB contact centre, three text excerpts (A – terms-of-conditions, B – privacy policy, and C – advertisement letter) covering typical customer questions were selected. Excerpts in German with a length of approximately 300 to 400 words were then professionally translated into plain language and into easy-to-read language. The translations were tested by four reviewers with cognitive disabilities and deemed as adequate and accessible. Further, all texts were analysed with the Flesch reading ease formula (Flesch, 1948), which showed a decrease of text difficulty compared to the original text in conventional language. Four versions of text presentation were then prepared on a website, including (1) the original text as the control condition, (2) the version in plain language, (3) a dynamic combination of the original with the easy-to-read language where participants had the option to toggle between the versions, and (4) a static combination where the easy-to-read version was presented in an additional box next to the original text. A total of 308 nondisabled participants read all three texts in a counterbalanced order and each text was randomly presented in one of the four versions. Reading time as well as text understanding based on multiple-choice questions and true-or-false statements were measured as performance indicators. Ratings for subjective comprehension, trust, text liking, perceived aesthetics, pragmatic quality, and hedonic quality were used as subjective measures. Additionally, participants rated the helpfulness of the additional easy-to-read text in the respective versions.

Results

Performance Measures. Reading duration of (A) the terms-of-conditions excerpt was significantly shorter for the original text in comparison to all the experimental conditions. No difference in reading time was found for (B) the privacy policy and (C) the advertisement letter. Regarding text understanding, no significant difference was found for any text (A, B, C) in any condition.

Subjective Measures. Regarding subjective comprehension, the versions in plain language were rated as better comprehensible compared to the originals for all the texts (A, B, C). The versions in plain language were also rated higher compared to the dynamic easy-to-read version for (A) the terms-of-condition and (B) the privacy policy excerpt. Regarding pragmatic quality, all experimental conditions were rated higher than the original text for (A) the terms-of-condition and (C) the advertisement letter. Further, the version in plain language was also rated higher than the easy-to-read versions for (A) the terms-of-condition excerpt. Ratings for trust, text liking, perceived aesthetics, and hedonic quality did not differ significantly among all the versions for each text. Both variants that combined conventional with easy-to-read text were deemed moderately helpful by the participants.

Discussion and Conclusion

Our results show that the proposed approaches to combine conventional with easy-to-read language did not undermine the experience of nondisabled users. In contrast to previous studies, no significant negative effects regarding text liking were found. However, we also did not observe any significant benefits regarding text understanding. We explain these differences with the chosen approach to combine the text variants, which seems to allow a more subtle presentation of easy-to-read text than in previous studies. At the same time, our variants may have been too subtle for a significant impact. An indicator for this interpretation is the result regarding the perceived helpfulness of the addition of easy-to-read texts. The moderate ratings by nondisabled users indicate that the presentation could be further optimised. Nevertheless, it is important to note that easy-to-read language mainly addresses people with cognitive impairments. From this perspective, our results show that a careful implementation of language simplification has the potential for more inclusive products. Further, the versions in plain language were perceived to be more comprehensible and to have a higher pragmatic quality. Perhaps a combination of plain language with easy-to-read language could make full use of the potential of language simplification.

Manuscript 3 – How Compliance with Web Accessibility Standards Shapes the Experiences of Users with and without Disabilities

Aim of the Study

Most predominantly used evaluation methods for web accessibility rely on compliance with standards (Abou-Zahra, 2008). This has also become a common complaint of web professionals, who frequently experience work on web accessibility as a box-ticking exercise (Holliday, 2020). However, despite the emphasis on conformance, current research has not provided a consistent answer regarding to what extent the needs of users with disabilities are covered by web accessibility standards. Further, it remains unclear what outcomes related to usability and user experience can be expected. While some authors have described large gaps in standards (e.g., Power et al., 2012; Rømen & Svanæs, 2011), other authors have found significant positive effects (e.g., Schmutz et al., 2017), which have also been ascertained for nondisabled users (e.g., Schmutz et al., 2016). Improving the overall quality of a product is a frequently used argument for web accessibility (Henry, 2006) and was also found to be one of the main influence factors in Manuscript 1. The study described in Manuscript 3 therefore aimed to contribute to a more differentiated understanding of what outcomes can be expected from compliance-based approaches to web accessibility.

Methods

In a randomised controlled experiment, 66 participants with visual impairments and 65 participants without visual impairments solved tasks on an online shop built with either low or high conformance to web accessibility standards. The design was inspired by former studies (Pascual et al., 2014; Schmutz et al., 2017), but the choice of an online shop represented a new context to complement previous findings. To differentiate the low- and high-conformance versions, the requirements of WCAG 2.0 were considered, and a total of 21 criteria were manipulated. As performance indicators, task completion rate and task completion time were measured. Subjective measures included scales for perceived task success, task satisfaction, perceived usability, visual aesthetic, pragmatic quality, hedonic quality, and likelihood to recommend. To complement these quantitative measures, participants were asked to provide feedback for each task in open-ended answers. These accounts were then coded according to their relation to web accessibility, usability, or user experience and according to their connotation with either positive or negative affects.

Results

Quantitative Measures. No statistically significant effects were found for any quantitative measure related to usability and user experience, neither for participants with visual impairments nor for participants without visual impairments.

Qualitative Measures. In open-ended answers, participants with visual impairments reported significantly more positive experiences. Participants without visual impairments reported significantly fewer positive experiences but also significantly fewer negative experiences for the high-conformance version.

Discussion and Conclusion

Our study design made it possible to explore the impact of compliance with web accessibility standards on outcomes related to usability and user experience. In contrast to previous studies, we did not observe significant positive or negative effects and we also had substantially smaller effect sizes for the quantitative measures. We mainly explain these differences through the study setup and the materials used. First, the fully online and unmoderated setup arguably favoured participants with solid skills in using the web and assistive technologies. Since more experienced users develop elaborate tactics to overcome web accessibility issues (Vigo & Harper, 2014), compliance with standards may have had less importance in the present study. Second, an online shop with common, highly standardised interaction patterns may have made it easier for participants to circumvent web accessibility hurdles than in studies with less familiar materials. We therefore conclude that depending on the users and context, beneficial effects on usability and user experience cannot be expected from compliance with web accessibility standards alone. However, the analysis of the qualitative measures shows that adopting standards remains an important building block. Its value is reflected in significantly more positive experiences by participants with visual impairments and significantly fewer negative experiences by participants without visual impairments while using the online shop compliant to web accessibility standards. However, participants without visual impairments also reported significantly fewer positive experiences in the compliant condition. Given that negative user experiences have a stronger impact on the overall experience (Vaish et al., 2008), we consider this a benefit of the version that was compliant with web accessibility standards. Overall, the present findings reveal a complex relationship between compliance with web accessibility standards and outcomes related to usability and user experience. As standards alone do not guarantee favourable results in every context, we suggest that conformance-based approaches should be seen as a first step in web accessibility and be complemented with user-centred or participatory design methods.

Manuscript 4 – My Train Talks to Me: Participatory Design of a Mobile App for Travellers with Visual Impairments

Aim of the Study

Following common web accessibility standards does not guarantee digital interactions that are comparable in value, quality, and efficiency for all user groups. As discussed in Manuscript 3, such comparable experiences require a more user-oriented perspective on web accessibility and a design process that complements conformance-based approaches. However, this more holistic perspective is rarely adopted (Oswal, 2019), and only a few tools and techniques have been developed to capture the subjective experiences of users with disabilities (Power et al., 2018). The case study detailed in Manuscript 4 explores a *participatory design* process. In this approach, users actively define and shape the design of a product (Bødker & Kyng, 2018), which makes it promising to include the perspectives of users with disabilities (Oswal, 2019). We detail the development of a mobile app that was codesigned by users with visual impairments in all the project phases. The case study was conducted in collaboration with Swiss Federal Railways. It pursued the goals of identifying and closing information gaps on journeys by public transport and of learning how participatory design can facilitate the provision of comparable experiences for users with disabilities.

Methods

The participatory design process was split into five phases: (1) In the *problem identification* phase, we asked travellers with visual, hearing, and motor impairments to report on their experiences regarding information gaps they confronted during journeys by public transport. In two workshops with a total of nine participants, we mapped a complete user journey where the participants introduced potential information gaps and rated these according to severity. These detailed problem descriptions were then used as input for (2) the *technical-feasibility* phase in which technical solutions were explored. This resulted in approaches to identify and provide information for the current train and the current train station to address the most pressing information gaps for travellers with visual impairments. With these technical components, a basic test app was built in (3) the *proof-of-concept* phase and distributed to a group of 34 interested travellers with visual impairments. Further, three exemplary journeys with 10 travellers in total were conducted to discuss the app's functionalities and design in a real context. Additionally, a total of 60 employees of Swiss Federal Railways were invited to personally experience the addressed information gaps. Based on the insights generated in the previous phases, we compiled the final interaction concept in (4) the *design* phase. The concept was then refined in collaboration with four blind users. Finally, versions for iOS and Android were created from scratch in (5) the *development* phase. Users that participated in the previous phases were invited to update their apps from the proof-of-concept phase and to provide feedback on the ongoing development.

Results

Travellers with visual impairments participated in all phases of the present case study. The co-design process allowed us to obtain a thorough understanding of information gaps during journeys by public transport and permitted design decisions in line with user needs. It further created a space for collaboratively drafting ideas, which made it possible to attain a level of quality that would arguably not have been achieved otherwise. For instance, an early version featured the concept of a master-detail pattern, providing a short overview of the travel information with an option to see more details. Travellers using screen readers deemed this concept as impractical in the present context since it requires browsing through an often-changing list and an additional click to look for further information. In close collaboration with the participants, a concept was outlined that uses a tab navigation at the bottom end of the app and reserved areas for the most important information. These reserved areas have a fixed position on the screen and enable quick access and orientation using a screen reader. Besides such design decisions, another important outcome of the participatory design process was its impact on stakeholders within the organisation. To come in touch with users with disabilities and to personally experience the inconvenience caused by the information gaps proved to be an effective tool for promoting awareness and knowledge about web accessibility at all organisational levels.

Discussion and Conclusion

In our case study, we showed how participatory design can facilitate creating a user experience that is comparable in value, quality, and efficiency for users with visual impairments. A co-design process is therefore a potential method to complement compliance-based approaches to web accessibility. Participatory design showed multiple benefits: First, it improved quality by optimising a product for user needs that go beyond what is covered with standards. Second, direct user involvement reduced the sensation of web professionals that web accessibility is mainly about ticking off a list of criteria. Third, it supported an organisation in developing awareness and knowledge at all organisational levels. For instance, collaborating with travellers with visual impairments sensitised various internal stakeholders, which contributed to a reduction in misconceptions regarding web accessibility. Although a participatory design process must be adjusted to fit the context of a specific product, our approach may inspire similar activities in other projects.

Discussion

Over the course of four manuscripts, we examined three overarching research questions related to why and how web professionals consider web accessibility. The first research question addressed in Manuscript 1 aimed to identify the key contributing factors in the adoption of web accessibility in practice. A systematic integration of previous research into the theory of planned behaviour allowed us to expand on past findings by narrowing down the most important aspects. In this process, we identified three key factors: (1) user advocacy, (2) self-perception as a specialist, and (3) product quality. These results served us as the foundation for two additional research questions that further explored the identified factors.

With the second research question, we focused on how web professionals see an improvement of overall product quality as a key factor for considering web accessibility. Both Manuscript 2 and 3 addressed this issue in a randomised controlled experiment. In Manuscript 2, we investigated nondisabled users and their perception of web information with reduced language complexity. This question became important since previous findings have shown unintended negative side effects on text liking and intention to revisit a website (Karreman et al., 2007; Schmutz et al., 2019). This could undermine the quality argument for implementing web accessibility in practice. In our study, we added new insights by demonstrating that easy-to-read language can be implemented without unintended side effects and that the potential of plain language should be further considered.

In Manuscript 3, we explored the impact of following web accessibility standards on the perceived overall quality of a product. Many methods for evaluating web accessibility strongly rely on standards (Abou-Zahra, 2008), and they play a dominant role in the daily work of web professionals (Holliday, 2020), even though it is controversial whether compliance alone can lead to satisfying usability and a positive user experience (e.g., Power et al., 2012; Rømen & Svanæs, 2011). By situating the study in the setting of an online shop and applying a fully unmoderated setup, we complemented previous findings with another context and with participants who were presumably more skilled users. Since we did not find any statistically significant effects, our results contrast with comparable studies (e.g., Pascual et al., 2014; Schmutz et al., 2017) and add to a more differentiated perspective on what can be expected from compliance with web accessibility standards alone.

Finally, research question three addressed user involvement as another key factor of why web professionals consider web accessibility in their products. Manuscript 4 explored how to facilitate the integration of users' perspectives in the context of web accessibility. We drew upon the proposition of using a participatory design approach (Oswal, 2019) as a means for capturing the subjective experiences of users with disabilities (Power et al., 2018). With the goal of closing substantial information gaps on journeys by public transport, travellers with visual impairments co-designed a mobile app with us. The case study covered the whole design process from problem identification to the final development of the mobile app. Our findings complement previous methodological discussions with an example of how participatory design can contribute to a thorough understanding of users' perspectives and of how participatory design is a promising approach for designing inclusive products that go beyond technical conformance.

Key Findings

User Involvement Has an Impact on Multiple Levels

Over the four manuscripts, the importance of user involvement becomes evident in multiple ways. As shown in Manuscript 1, the intention of web professionals to consider web accessibility is strengthened when users actively promote their needs. Involving users with a variety of abilities in the design process can facilitate such feedback processes. Further, as highlighted in Manuscripts 4, participation contributes to establishing a thorough understanding of users' perspectives and prevents forcing users with disabilities to passively accept suboptimal or retrofitted designs (see also WHO, 2011). In consequence, user involvement is also key if web professionals want to go beyond compliance with web accessibility standards, a step whose importance we outlined in Manuscript 3.

As discussed in Manuscript 4, user involvement also had an impact beyond the product level. Interactions between users with visual impairments and stakeholders in the company helped foster awareness and knowledge at all organisational levels. It helped reduce misconceptions regarding users with disabilities and the concept of web accessibility in general. For the project team, communicating the "why" of web accessibility was made easier. These results are in line with strategies discussed in Manuscript 1 and with similar recommendations by other authors (e.g., Hassell, 2019; Kalbag, 2017; Urban & Burks, 2006). However, such approaches also involve pitfalls, namely, seeing users with disabilities as unequal contributors to a project or treating them as a spectacle (Bennett & Rosner, 2019). Since users with disabilities are a heterogenous group, it is further a challenge to achieve adequate representation (Henry, 2007; Horton & Quesenbery, 2014). Web accessibility efforts are often focused on users with visual impairments, and users with hearing, motor, or cognitive impairments are addressed to a lesser extent (Vollenwyder et al., 2020). Rather than reducing misconceptions regarding web accessibility, this bias may unintentionally confirm unwanted clichés.

Standard Conformance as a First Step

The quality of a service on the web and in mobile apps can be enhanced through considering web accessibility. In Manuscript 4, we showed how it contributes to an optimal experience for users with disabilities, while in Manuscript 2, nondisabled users' subjective text comprehension was enhanced. This is in line with product quality as one of the key determinants of why web professionals consider web accessibility, as found in Manuscript 1. That all user groups benefit from web accessibility is a frequently named argument for convincing stakeholders (Henry, 2006) and has also been documented in other studies (e.g., Schmutz et al., 2017).

However, as shown in Manuscript 3, the degree to which web accessibility efforts contribute to the overall quality of a product depends on how it is handled in the design process. We discussed this issue mainly from the perspective of compliance with web accessibility standards and their predominant role in practice (Holliday, 2020; Horton et al., 2015). Standards such as the widely applied WCAG 2.0 have been shown to be vital for establishing basic accessibility to technology (Power et al., 2018) and to be a foundation for a wide range of evaluation methods (Abou-Zahra, 2008). These advantages contrast with our results from Manuscript 3, in which we show that depending on the users and the context, compliance alone does not guarantee beneficial outcomes in usability and user experience. We therefore propose using compliance with standards as a starting point and complementing this foundation with user-centred design methods, as discussed in Manuscripts 2 and 4. Such a combination seems to be a promising path toward enhancing the quality of a product for as broad an audience as possible. It further helps avoid the common misconception that there is a quick fix for web accessibility and prevents wrong expectations from stakeholders about what can be achieved by complying with standards alone (Cooper et al., 2012; Horton et al., 2015).

Strengthen Web Accessibility in the Design Process

Web and mobile apps are a fast-evolving field with constant change, which requires that web professionals keep track of developments and that users constantly adapt to new experiences (Harper & Chen, 2011). To catch up with recent developments, product teams must work on a wide range of topics, including web accessibility. In this environment, a lack of awareness in less technical roles (Vollenwyder et al., 2020) and a focus on compliance-based approaches, as discussed in Manuscript 3, become obstacles to creating accessible products. These circumstances tend to delay considering web accessibility to later stages of the design process and lead to retrofitting and to unsatisfying experiences for users (Petrie & Bevan, 2009). They further contribute to web professionals' perception of web accessibility as a box-ticking exercise

(Holliday, 2020). Establishing robust processes is therefore a key requirement for designing inclusive products.

In Manuscript 4, we discussed an example of a design process that introduces web accessibility considerations at all stages of development, including in the early phase of problem identification. Manuscript 2, on the other hand, focused on the design and evaluation phase as well as on the given problem of unintended side effects on nondisabled users. In both manuscripts, we combined web accessibility with user-centred design methods and closely tied them to outcomes related to usability and user experience. Such an approach is convincing because of the conceptual overlap (Sauer et al., 2020), the idea of designing for as many people as possible (Kalbag, 2017), and our previously discussed suggestion of involving users in development. However, the ideas outlined in Manuscripts 2 and 4 are not necessarily the ideal path for every service in every context. Strategies for expanding awareness, establishing processes, and continually evolving a product should be considered individually for each setting (see also Hassell, 2019).

Expand and Enhance Personal Commitment

Personal commitment is a powerful driving force for web accessibility. This commitment has been referred to in various ways, for example, as pride and ambition (Velleman et al., 2017), as an understanding that accessibility is the right thing to do (Henry, 2006), or as an ethical consideration (Yesilada et al., 2012, 2014). Personal commitment also comprised part of our results in Manuscript 1, in which the salient belief that web accessibility belongs to one's individual professional role emerged as a key factor. Meanwhile, we have also seen that not all specialists working on web and mobile apps feel a personal responsibility (Vollenwyder et al., 2020). It therefore seems important to expand and enhance the awareness that web accessibility is a concern for everyone involved in designing inclusive products.

There is an interplay between user involvement in the design process and expanding awareness of the individual's professional role. In Manuscript 4, meeting and working with users with disabilities helped reduce misconceptions and foster awareness. This worked at all organisational levels and specifically addressed the responsibility of less technical roles. Further, organisations should invest in learning materials and training to establish a shared understanding of how inclusion benefits all users and how all professional roles can address it in the design process (Coverdale et al., 2022; Yesilada et al., 2014). Moreover, in Manuscript 1, we discussed attempts to encourage professionals to share personal experiences and examples regarding web accessibility with their peers. Through sharing advice, building confidence, and developing good practices, exchanges with other professionals occupying similar roles may help individuals approach comparable challenges.

Limitations

Some limitations of the present work need to be addressed. First, the key contributing factors discussed in Manuscript 1 were identified based on a single sample of web professionals, so relevant background factors may not have been fully addressed. In our study, participants were mainly based in Switzerland and reported having a mostly favourable attitude towards web accessibility. It is possible that such aspects introduced a bias in the ratings of the various influence factors. For example, since factors such as self-perception as a specialist are likely to be related to personal attitudes towards web accessibility, they may have been overestimated in our study (see also Ajzen, 2011).

Second, our model examined salient beliefs influencing the intention to consider web accessibility but did not include the step from intention to actual behaviour. The theory of planned behaviour that we applied recommends conducting a follow-up study to assess moderating factors (Fishbein & Ajzen, 2010). In our case, this would have made it possible to study aspects such as limited monetary or human resources and their influence on considering web accessibility.

Third, we worked with materials specifically created for an experimental setup in Manuscripts 2 and 3. While this choice was made intentionally to allow for methodological rigour, it potentially reduces the external validity of our results. Further, our decision to conduct both studies fully online and unmoderated may also have influenced the outcomes. For instance, since solid computer skills were required to participate in the first place, this may have imposed a self-selection bias for more experienced users. While this procedure was intended to allow for new insights, it reduces the comparability with previous studies.

Finally, both Manuscripts 2 and 4 were conducted in the context of public transport. Since public transport may belong to the daily travel routines of our participants, this setting is linked with certain attitudes and experiences that may differ in other environments. Additionally, public funding and legal obligations are often involved. This may influence participants' expectations regarding the accessibility of web and mobile apps in this context.

Implications for Research

Direction 1: Sampling Strategies

Our first suggestion for future research addresses user involvement as a key component of the inclusive design process. Users with disabilities are as diverse as any other people, with varied experiences, expectations, and preferences. People have individual forms of a disability with large variations or have a combination of multiple disabilities. They may further use differing interaction techniques, adaptive strategies, and assistive technologies (WAI, 2019). The common broad categories of visual, auditory, motor, and cognitive impairments are therefore hardly sufficient for categorising and selecting participants for user involvement. Research and practice thus face the challenge of how to find and select people with disabilities for user-centred design methods. Suggestions such as focusing on target users (e.g., prioritising users with cognitive impairments for a website providing news in simplified language) or focusing on the highest impact (e.g., optimising for a certain standard setup of assistive technologies when designing a company's internal website; see Henry, 2007) are valuable starting points for further exploring the advantages and disadvantages of different sampling strategies.

Direction 2: Methodological Knowledge

Our results highlight the importance of complementing conformance-based methods with user-centred design. This opens a wide array of potential qualitative and quantitative methods that are established in the context of usability and user experience but are often less familiar in the context of web accessibility (Sauer et al., 2020). Future research could address this issue by exploring the most promising methods for establishing a thorough understanding of users' perspectives in all phases of an inclusive design process. Some methods may need adaptations for this purpose. For instance, in Manuscript 4, we tested usability with a low-fidelity prototype; this required a simple prototype built with web technologies instead of more common wireframes to be accessible for users with visual impairments. Further, due to the diversity of users with disabilities, it will never be possible to cover all the potential issues with user involvement. Web accessibility standards will therefore remain important for ensuring basic access, and further insights regarding how to optimally combine conformance-based and user-centred approaches would be valuable.

Direction 3: Integration in Common Design Processes

In practice, design processes rarely start from scratch, and most of the time web accessibility must find its place in an existing setting (Arrue et al., 2008). Integration into widely used, agile development processes with fast iterations especially remains a challenge (Miranda & Araujo, 2022). With short development cycles, user research and testing activities must fit into a tight schedule. In this sense, web accessibility shares the same challenges as the related concerns of usability and user experience. Due to these common difficulties and the discussed conceptual overlap, it would make sense to further explore how web accessibility, usability, and user experience can be more closely connected. Further, in most development processes, considering web accessibility is not part of all stages and is primarily restricted to the design and implementation phase (Vollenwyder et al., 2020). First attempts to better understand the diffusion of web accessibility awareness in various design stages should therefore be further advanced. The apparent lack of attention in the research phase and in the continuous development after a first release should be addressed.

Direction 4: Addressing All Professional Roles

Our last suggestion considers the importance of establishing a personal commitment for web accessibility in all professional roles involved. Since a project team often consists of a variety of professional backgrounds with different duties and responsibilities, support regarding web accessibility should be tailored to specific needs. Future directions could focus on finding optimal ways to foster awareness and knowledge and to facilitate work on web accessibility. Special attention should be given to less technical roles (Yesilada et al., 2014). Further, besides concrete materials for daily work, building a community and sharing best practices regarding web accessibility should also be promoted.

Implications for Practitioners

Web Professionals

Gaining a thorough understanding of users' perspectives is essential to working on web or mobile apps. On the one hand, this includes a general understanding of why certain requirements are part of web accessibility standards (e.g., why keyboard focus must have a meaningful order). On the other hand, it also requires knowledge of how these requirements are applied in a product-specific context (e.g., what is the most meaningful way for the navigation on my website to receive keyboard focus). In practice, building this expertise involves a journey consisting of multiple steps: from becoming aware that web accessibility is an issue, to learning about standards and including them in work practice, to finally understanding why some users may rely on specific requirements (for an example of such a journey, see Fisher, 2019). We therefore recommend that web professionals invest in acquiring knowledge and familiarising themselves with common guidelines and evaluation tools. In a second step, getting in touch with actual users becomes essential. This helps push personal understanding of web accessibility beyond mere conformance with standards and sets up a path for designing truly inclusive products. Further, professionals should not hesitate to share their examples and best practices with colleagues to help them on their own journeys.

Organisations

Organisations that want to embed inclusion in their culture must actively foster awareness and knowledge at all organisational levels. Our results show that giving users with disabilities a voice inside an organisation is an effective way to achieve this goal. Such involvement can be facilitated in various ways, for instance, by offering easy ways to provide feedback regarding web accessibility, by introducing an advisory board, or by building a user community. It is, however, important to see the involved users as partners and to address the issues they raise seriously. Further, organisations should offer resources for their members to acquire knowledge and skills regarding web accessibility. Here, the needs of various professional roles should be addressed specifically since the responsibilities of daily work on web accessibility can fundamentally differ. Finally, we recommend setting clear goals that do not solely focus on compliance with web accessibility standards. For example, an organisation can aspire to compliance with all the AA criteria of WCAG 2.0 and complement this goal with a commitment to regular usability tests with users with disabilities.

Public Sector

Especially for small and medium-sized organisations, establishing such awareness and knowledge can be an overwhelming task. We therefore recommend that the public sector supports organisations in their transition to more inclusive digital products. This could be done, for example, by hosting events to raise awareness for web accessibility, by connecting users with web professionals in organisations, or by providing resources for best practices. Promoting good examples, for instance, by awarding the best inclusive digital product of the year, can also help provide orientation for organisations and highlight how web accessibility benefits overall quality. Further, strengthening web accessibility in the education of web professionals would help establish knowledge and skills and strengthen personal commitment to the topic. Additionally, education provides opportunities to address how all professionals involved in designing web and mobile apps contribute to web accessibility and to shift the main responsibility away from the primarily technical roles.

Conclusion

The development of web and mobile apps is a fast-paced and rapidly changing field. Every day, opportunities for equal participation in society for people with disabilities arise from this technological change. With our research in the present thesis, we aimed to strengthen this potential. Based on empirical evidence, we outlined key determinants of why web professionals consider web accessibility and deepened the understanding of how to address these determinants in the design process. Following the recommendations to involve users, to see conformance with standards as a first step, to strengthen web accessibility in the design process, and to expand personal commitment can provide a solid foundation for inclusive design practices. Further, we presented implications for research and practitioners for advancing the field in the future.

I hope that by including the richness of human diversity in designing our living environment, we can expand and enhance opportunities for everyone.

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Appendix

Curriculum Vitae

General Information

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Publications

2021 Schneider, A., Krueger, E., **Vollenwyder, B.**, Thurau, J., & Elfering, A. (2021). Understanding the relations between crowd density, safety perception and risk-taking behavior on train station platforms: A case study from Switzerland. *Transportation Research Interdisciplinary Perspectives, 10*, 1–11. https://doi.org/10.1016/j.trip.2021.100390

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Full length article

Salient beliefs influencing the intention to consider Web Accessibility

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ABSTRACT

Web Accessibility aims to provide usable web information and services to as many people as possible. Despite the availability of standards and the presence of legal obligations, Web Accessibility often remains unsatisfactory. Through a multi-step approach, the present study addresses the question of how web practitioners form their intention to consider Web Accessibility in the development process. Based on a systematic literature review, twelve main salient beliefs influencing the intention to consider Web Accessibility were identified. Applying the Theory of Planned Behavior, a theoretical model integrating these main salient beliefs was compiled and a questionnaire to test the model developed. A total of 342 web practitioners in various professional roles answered the questionnaire in an online study. Path analysis revealed that intention to consider Web Accessibility is stronger when users actively promote their needs, when web practitioners see Web Accessibility as part of their professional role, and when the consideration of Web Accessibility is perceived as beneficial for the quality of a product. Hence, it is recommended to involve users with a variety of abilities in the development process, to emphasize the responsibility and specialist role of web practitioners, and to actively promote Web Accessibility as a quality feature of a product.

1. Introduction

Providing accessible information and services on the web is a demanding task. With the rise of the web as an ubiquitous part of daily private, social, economic and political life, web practitioners face the challenge of addressing the needs of users that differ considerably in their abilities, aptitudes, and attitudes (Horton & Quesenbery, 2014). Sensory (e.g., vision, hearing), motor (e.g., tremor, limited use of hands) and cognitive (e.g., learning disabilities, attention deficits) impairments can result in a variety of barriers to web use. Such issues substantially limit the potential of the web as an enabler for equal participation in society (Henry, 2006). To prevent the emergence of barriers, Web Accessibility promotes solutions that allow for heterogeneity, flexibility and device independence (Harper & Yesilada, 2008a). Lazar (2004) compares accessible websites to accessible buildings that can be entered and navigated with ease by means of curb cuts, ramps and elevators. Web Accessibility therefore refers to "the degree to which a website is usable by as many people as possible" (Kalbag, 2017, p. 3).

In recent years, guidelines as well as legal demands for Web Accessibility have been introduced in several countries worldwide (Waddell, 2006). However, the adoption of given standards remains a widely neglected topic (see Section 2). The goal of the present study is to identify the contributing factors underlying this neglect. For this reason, the perspective of web practitioners and their intention to consider Web Accessibility in the development process is adopted. Building upon previous studies, a systematic literature review was conducted, revealing twelve main salient beliefs among web practitioners. These salient beliefs were then integrated within the Theory of Planned Behavior (see Section 3) and rated by web practitioners (see Section 4). Findings indicate three key determinants: Active promotion of user needs, the perception of Web Accessibility as a part of a web practitioner's professional role, and the perception of Web Accessibility as beneficial for product quality (see Section 5).

2. Background

2.1. Challenges for web practitioners

General awareness of Web Accessibility, or the lack thereof, is necessary precondition and potential hurdle towards implementing Web Accessibility. A majority of web practitioners involved in the development process, especially in technical roles, have acquired at least a basic awareness of Web Accessibility. In contrast, non-technical and management roles tend to be less aware (Yesilada, Brajnik, Vigo, & Harper, 2014; Freire, Russo, & Fortes, 2008a, b). This lack of awareness

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Table 1
Overview of studies analyzed in the systematic literature review.

First Author	Year	Title	Method	N	Sample
De Andrés	2010	Factors influencing web accessibility of big listed firms: an international study	Content analysis	108	Firm websites
De Andrés	2009	Economic and financial factors for the adoption and visibility effects of Web accessibility: The case of European banks	Content analysis	51	Bank websites
Ellcessor	2014	< ALT = "Textbooks" >: Web Accessibility Myths as Negotiated Industrial Lore	Content analysis	40	Web references (1997–2012)
Farrelly	2011	Practitioner barriers to diffusion and implementation of web accessibility	Interviews	23	Web practitioners
Freire	2008a	A survey on the accessibility awareness of people involved in web development projects in Brazil	Survey	613	Web practitioners
Freire	2008b	The perception of accessibility in Web development by academy, industry and government: a survey of the Brazilian scenario	Survey	613	Web practitioners
Leitner	2016	Web accessibility implementation in private sector organizations: motivations and business impact	Evaluation; Interviews	12	Managers
Putnam	2012	How do professionals who create computing technologies consider accessibility?	Survey	199	UX and HCI professionals
Trewin	2008	Accessibility challenges and tool features: An IBM Web developer perspective	Survey	49	Web practitioners
Velleman[a]	2017	Factors explaining adoption and implementation processes for web accessibility standards within eGovernment systems and organizations	Interviews	18	Municipalities stakeholders
Yesilada	2012	Understanding web accessibility and its drivers	Survey	300	Web practitioners

Note: [a]Published online 2015.

often causes Web Accessibility issues to be deprioritized compared to other requirements (Velleman, Nahuis, & van der Geest, 2017). Additionally, insufficient knowledge brings up a row of potentially harmful conceptions of Web Accessibility. Oft-mentioned beliefs include that Web Accessibility compromises aesthetics and technologically advanced solutions, that Web Accessibility either requires high expenses or no cost at all, that Web Accessibility concerns only people with visual impairments, or that the topic is solely the developers responsibility (Ellcessor, 2014; Henry, 2006). Such statements stand in contrast with findings that show that Web Accessibility has no negative impact on aesthetics (Mbipom & Harper, 2011; Petrie, Hamilton, & King, 2004) and improves performance and perceived usability for all user groups (Schmutz, Sonderegger, & Sauer, 2016; 2017a; 2017b). Fostering awareness and knowledge on all organizational levels is therefore an important initial step for organizations wanting to provide accessible solutions (Urban & Burks, 2006).

A further challenge is the formation of adequate knowledge and skill for the actual implementation by all involved web practitioners. Effective Web Accessibility requires a thorough understanding of how design and implementation of a solution can address the needs of users with disabilities. Broad classifications such as people with visual, hearing, motor, or cognitive and learning impairments offer web practitioners only a rough idea about potential accessibility barriers users may face and how to overcome them (for an introduction to these categories, see Barreto, 2008; Cavender & Ladner, 2008; Trewin, 2008; Lewis, 2008). Understanding potential accessibility barriers becomes even more complex due to individual use of assistive technologies like screen readers, screen magnifiers and personalized stylesheets (Edwards, 2008; Hanson, Richards, & Swart, 2008; Thatcher, 2006), which are used at unequal skill levels (Vigo & Harper, 2014). Moreover, the above named categories do not include temporary (e.g., a broken arm) or situational (e.g., no audio available) impairments, which increase the number of affected users to a much greater extent (Farrelly, 2011). Further, web practitioners have to be able to meet all requirements with their technology of choice. The heterogeneity of technologies used on the web is a major strength regarding flexibility and adaptability, but also poses a major challenge regarding Web Accessibility (Harper & Chen, 2011). Hence, web practitioners have to accept that there is no simple one-size-fits-all solution (Harper & Yesilada, 2008a).

2.2. Guidelines and state of adoption

Several Web Accessibility guidelines are available as resources to overcome the aforementioned challenges of implementing accessible web services (for an overview, see Harper & Yesilada, 2008b). They serve as a foundation upon which to build a shared understanding regarding the needs of people with disabilities, as a reference for specific design decisions in the development process, and as a standard for the evaluation of Web Accessibility. Guidelines are therefore vital in the creation of accessible solutions (Henry, 2006). The most widely applied set of recommendations are the Web Content Accessibility Guidelines 2.0 (WCAG), which are built around four principles: (1) perceivable, (2) operable, (3) understandable and (4) robust (Caldwell, Cooper, Reid, & Vanderheiden, 2008). Despite the qualities of the WCAG, they have also drawn considerable criticism. For instance, it has been argued that compliance by itself does not guarantee a satisfying user experience (Aizpurua, Arrue, & Vigo, 2015, 2016; Pereira & Archambault, 2018; Petrie & Kheir, 2007; Power, Freire, Petrie, & Swallow, 2012), that the guidelines are difficult to evaluate (Brajnik, Yesilada, & Harper, 2012, 2011) and that cognitive impairments are not adequately taken into account (Karreman, van der Geest, & Buursink, 2007). However, the WCAG are widely accepted as a benchmark for accessible solutions and are referenced in the policies of several countries worldwide (Waddell, 2006).

Despite the availability of the second edition of the WCAG since

Table 2
Main salient beliefs influencing the intention to consider Web Accessibility identified from the systematic literature review.

Factor	TPB	Description	Impact
Personal effort	Attitude	Consideration of Web Accessibility requires a personal effort.	Negative
Social responsibility	Attitude	It is possible to support other people with Web Accessibility.	Positive
Business opportunity	Attitude	Web Accessibility provides an opportunity to reach more clients.	Positive
Product quality	Attitude	Web Accessibility improves the overall quality of the work.	Positive
User advocacy	Subjective Norm	Users demand for Web Accessibility.	Positive
Legal obligations	Subjective Norm	Legal obligations require Web Accessibility.	Positive
Self-perception as specialist	Subjective Norm	Web Accessibility is considered as part of ones role as a web specialist.	Positive
Awareness and priorities	Perceived Control	The employer has a high awareness of and prioritizes Web Accessibility.	Positive
Requirement conflicts	Perceived Control	Web Accessibility conflicts with other requirements.	Negative
Technical compatibility	Perceived Control	Technical constraints make it difficult to consider Web Accessibility.	Negative
Limited resources	Actual Control	Lack of time and money.	Negative
Knowledge and skills	Background Factors	Lack of knowledge and skill.	Negative

2008 and their incorporation in legal obligations, Web Accessibility often remains at an unsatisfactory level. Neither public (Jaeger, 2006; Kuzma, 2010; Shi, 2007; Martins, Gonçalves, & Branco, 2017; Nurmela, Pirhonen, & Salminen, 2013), educational (Hackett & Parmanto, 2005; Sloan, Gregor, Booth, & Gibson, 2002), nor private (Gonçalves, Martins, Pereira, Oliveira, & Ferreira, 2012; Hackett, Parmanto, & Zeng, 2005) sector websites show full compliance with standards. A considerable body of research addresses the question of why and how Web Accessibility is taken into account (for a comprehensive overview, see Table 1). Attempts range from industry surveys (e.g., Freire, Russo, & Fortes, 2008b; Putnam et al., 2012; Yesilada, Brajnik, Vigo, & Harper, 2012), to content analysis (e.g., De Andrés, Lorca, & Martínez, 2010, 2009; Ellcessor, 2014), and to the proposition of theoretical models (e.g., Farrelly, 2011; Velleman et al., 2017). These studies reveal a wide range of personal and organizational factors influencing the adoption of Web Accessibility (for the main factors derived from the systematic literature review, see Table 2). However, it remains unclear to what extent different factors shape web practitioners' intention to adopt accessibility standards. A better understanding of the most important factors would allow researchers and practitioners to further focus their efforts.

2.3. Theory of Planned Behavior

As a means to integrate and to expand on previous research, the present work proposes the introduction of the Theory of Planned Behavior (TPB, Fishbein & Ajzen, 2010; Ajzen & Fishbein, 2005). TPB is a robust and widely applied theory (Ajzen, 2011) with a well-documented methodological procedure (see appendix in Fishbein & Ajzen, 2010). It has also been frequently applied in human-computer interaction, for instance, in investigating persuasive system design (Schneider, Moser, Butz, & Alt, 2016), e-learning adoption (Chu & Chen, 2016), cyberloafing (Askew et al., 2014), and the acceptance of e-portfolios (Ahmed & Ward, 2016).

Central to TPB is the concept of *intention*, which is the immediate antecedent of the actual performance of a behavior. The relation between *intention* and behavior is mediated by *actual behavioral control* and therefore by external factors that cannot be controlled by an individual. According to TPB, *intention* is formed by three main factors: (1) *attitude*, the personal favorable or unfavorable opinion regarding a behavior, (2) *subjective norm*, the perceived social pressure to perform or not perform a behavior, and (3) *perceived behavioral control*, the perceived ease or difficulty of performing a specific behavior. A favorable *attitude* and *subjective norm* as well as high *perceived control* lead to a strong *intention* to perform a behavior, although the relative importance of the three factors can vary across behaviors (Fishbein & Ajzen, 2010). The three factors are in turn influenced by *salient beliefs*. Specifically, attitude is influenced by *behavioral beliefs*, subjective norm by *normative beliefs*, and perceived behavioral control by *control beliefs*. All salient beliefs emerge from a person's individual (e.g., personality, values), social (e.g., education, culture) and informational (e.g., knowledge, media) background (Ajzen & Fishbein, 2005).

3. Literature review and model building

3.1. Review procedure

The Scopus database was searched for titles, abstracts and keywords containing the term “Web Accessibility”. Scopus was chosen because it includes most scientific journals and conferences relevant to Web Accessibility (e.g., Universal Access in the Information Society, International Conference on Computers Helping People with Special Needs). The search covered the years 2008–2017. This time frame was chosen due to the publication of the WCAG in 2008 (Caldwell et al., 2008). This search resulted in a total of 925 publications. Papers were screened for four criteria: (1) Papers had to discuss factors that influence the perception or adoption of Web Accessibility standards by stakeholders involved in the web development process and (2) provide quantitative or qualitative empirical data. In addition, only (3) original full papers (4) written in English were included. The first author and a second independent rater screened and categorized potential papers as “definitely include” and “maybe include”. This resulted in a total of 29 papers with a good inter-rater agreement (Brennan-Prediger $\kappa = 0.96$, see Gwet, 2014). Subsequently, the raters reviewed their categorizations regarding the screening criteria and agreed on a selection of 11 papers (see Table 1). All influence factors discussed in the selected papers were then extracted by the first author and categorized according to whether they had a positive or negative impact on web practitioners' consideration of Web Accessibility. In total, 118 factors were extracted.

In a second step, all influence factors were clustered during an affinity diagram workshop (Holtzblatt & Beyer, 2014) with 5 participants, all members of the affiliated research institute. For instance, the cluster *business opportunity* included factors such as “addressing more clients” (Freire et al., 2008b), “new market niche” (Ellcessor, 2014), and “differentiation” (Leitner, Strauss, & Stummer, 2016). This resulted in 12 main salient beliefs, which are described in Table 2. These main salient beliefs were then grouped according to their corresponding factors in the TPB model as presented in Fig. 1. For instance, *business opportunity* was considered a salient belief mainly influencing attitude because it can promote a personal favorable opinion with regards to considering Web Accessibility.

3.2. Questionnaire construction

Following the guide for the construction of TPB standard questionnaires (Fishbein & Ajzen, 2010), items based on the compiled model were developed. The authors stress the need to clearly specify the behavior of interest in terms of target, action, context and time, as well as target research population. For the present work, behavior of interest

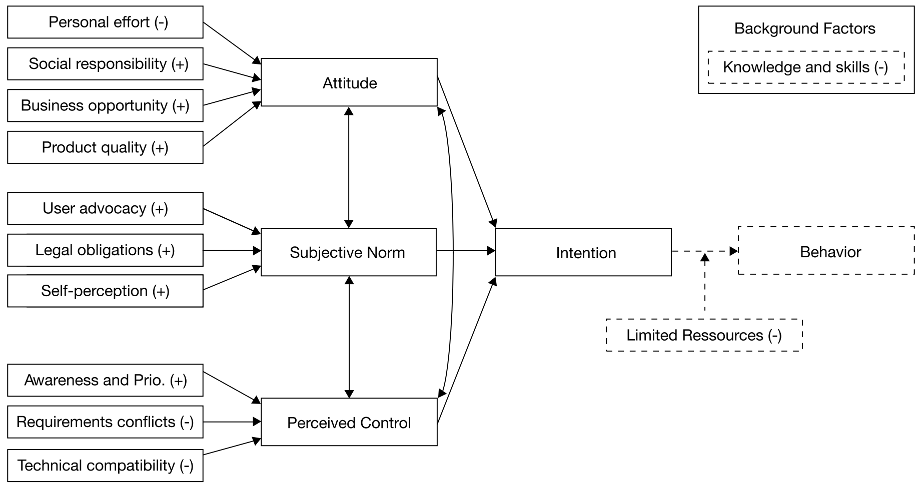

Fig. 1. TPB model of intention to consider Web Accessibility derived from the systematic literature review. Dashed lines indicate parts described in the TPB that were not tested in the present study.

was defined as "consideration of Web Accessibility in the next project" and research population as "specialists that participate in the creation of websites and web applications". Item formulations proposed in the guide were slightly adapted to achieve a consistent answer pattern for 7-point-Likert scales (1 = completely disagree, 7 = completely agree). All salient beliefs were assessed with two items, one to evaluate the outcome (e.g., "The consideration of Web Accessibility in my next project is an opportunity to reach more clients with my work."), and a second to assess the strength of the belief (e.g., "Reaching more clients is desirable to me."). Attitude, subjective norm, and perceived control were assessed with two items and intention with a single item following the proposed formulations by Fishbein and Ajzen (2010). The final TPB questionnaire contained a total of 31 items and is presented in appendix A.

A pilot questionnaire was distributed to 12 web practitioners (age $M = 33.7$, $SD = 8.0$, range 21–48; 4 women, 8 men). Participants were selected to represent a diversity of roles and expertise in web development. User researchers, interaction designers, visual designers and frontend developers were included with three participants each. After filling in the questionnaire, participants were interviewed with respect to their feedback on item wording, missing answer options, and the average time required to complete the questionnaire. Furthermore, all participants were asked to explain the meaning of each item regarding the 12 factors to ensure shared understanding of the items as intended (DeVellis, 2017). Responses were used for the final revision of the questionnaire.

4. Main study

4.1. Participants

A total of 345 web practitioners completed the online questionnaire. Following recommendations to include 10 participants for every free parameter (Kline, 2016), a sample size of 350 was targeted. Recruitment was conducted via two ways: (1) the online survey was advertised over various computer science and human-computer interaction newsletters and mailing lists across Switzerland. The study description addressed "all specialists who participate in the creation of websites and web applications (developers, designers, project managers, etc.)". As an incentive, participants could take part in a lottery for two gift vouchers for 50 Swiss Francs (about 42 Euros). Overall, 164 participants were recruited via this channel. (2) Participants were also recruited via TestingTime, a Switzerland-based agency specializing in recruiting study participants. Participants received a payment of 5 Swiss Francs (about 4.20 Euros) for their participation. Overall, 181 participants participated in the online study via TestingTime.

4.2. Data cleaning

Three participants were subsequently removed from the sample: one participant was excluded because of a response time of less than 2 min (duration $M = 11.9$, $SD = 9.0$, range 2–56) and two participants were excluded because their response time exceeded one hour. Further, inspection of same answers sequences in the TPB questionnaire revealed a maximum of 25 out of 32 (78%), which was deemed unproblematic for the present study (Curran, 2016).

4.3. Sample description

A total of 342 participants (age $M = 32.6$, $SD = 9.0$, range 18–65; 127 women, 204 men, 11 non-binary or not specified) were included in the main analysis. About half of the participants ($N = 162$) were recruited via newsletters and mailing lists, whereas the other half (180) were paid participants.

The majority of participants completed the questionnaire in German ($N = 211$), followed by English (105) and French (26). Participants reported their main role as web practitioners, the largest groups being professionals in functional testing (64), management (43), project management (34), development (32), product owner (31) and visual design (31). Compared to other employees at their organization, participants reported moderate personal interest in ($M = 5.24$, $SD = 1.34$) and knowledge of ($M = 4.54$, $SD = 1.54$) Web Accessibility (both 7-point Likert scale, 1 = very low, 7 = very high). Twenty-one participants reported to have a disability, including visual ($N = 11$), hearing (3), and motor (2) impairments.

Most participants worked in large organizations with more than 250 employees ($N = 129$), followed by middle sized organizations with 10–250 employees (112) and small organizations with under 10 employees (98). Organizations were active in the private sector (227), public sector (83), science and education (59), trusts, societies or non-governmental organizations (43), or not further specified (34). The main geographical regions of the organizations were Switzerland (159), Europe (106), worldwide (53) and other individual countries (17). Regarding legal obligations concerning Web Accessibility, participants stated that a majority of their organizations are not obliged to provide accessible solutions (156), followed by organizations that were fully (82) and partially (17) obliged. A sizable amount of participants was not aware of the exact legal requirements of their organization (77).

4.4. Procedure

Participants were first asked to describe their current work setting, their professional role, and the size, domain and location of their organization. Then they rated their personal interest ("How do you rate your level of interest in Web Accessibility compared to other employees at your company or organization?"), specific knowledge ("How do you rate your level of knowledge in Web Accessibility (reasons, legal obligations, etc.) compared to other employees at your company or organization?") and legal obligations of their organizations to consider Web Accessibility. Next, the TPB standard questionnaire was presented (see Appendix A). Questions were randomized to avoid order effects. Finally, participants provided demographic information.

4.5. Materials

Due to the multilingual setting in Switzerland, the survey was prepared in German, French and English. The original version was developed in German and translated to English by the first author, whereas the French version was translated by a native speaker. Both translations were double-checked by a second independent native speaker. All involved translators were trained experts in Human-Computer Interaction and familiar with terms and topics used by the target audience.

4.6. Data analysis

4.6.1. Data preparation

Data was aggregated according to the TPB guidelines (Fishbein & Ajzen, 2010). Salient beliefs were calculated by multiplying the outcome evaluation rating (e.g., "The consideration of Web Accessibility in my next project is an opportunity to reach more clients with my work.") with the strength of the belief rating (e.g., "Reaching more clients is desirable to me."), resulting in a score ranging from 1 to 49. Attitude, subjective norm and perceived behavioral control were calculated as arithmetic means of two items assessing these constructs, resulting in a range from 1 to 7.

4.6.2. Model estimation

A path analysis model was estimated using the lavaan package version 0.5–23 (Rosseel, 2012) for R. Descriptive statistics for all variables used in the model are presented in Table 3 and Spearman correlations among the variables in Table 4. Multivariate normality was not given (Mardia tests:, $p < .001$; $Z_{Kurtosis} = 10.74$, $p < .001$), therefore, a maximum likelihood estimation with Huber-White standard errors and a Yuan-Bentler based scaled test statistic was used (Rosseel, 2012). Inspection of fit indices indicated an unsatisfying fit (compare

Table 3
Main salient beliefs influencing the intention to consider Web Accessibility.

#	Factor	M	SD	Skewness	Kurtosis
1	Personal effort	11.87	8.87	1.31	1.77
2	Social responsibility	35.08	12.22	−0.58	−0.63
3	Business opportunity	28.92	14.23	−0.05	−1.19
4	Product quality	33.61	12.27	−0.56	−0.55
5	User advocacy	23.22	12.78	0.38	−0.81
6	Legal obligations	19.92	14.21	0.64	−0.75
7	Self-perception as specialist	17.85	11.63	0.72	−0.34
8	Awareness and priorities	15.90	12.51	0.97	0.12
9	Requirement conflicts	17.87	12.88	0.59	−0.55
10	Technical compatibility	16.91	12.12	0.63	−0.41
11	Attitude	5.43	1.24	−0.72	0.19
12	Subjective Norm	4.15	1.48	−0.07	−0.87
13	Perceived Control	3.99	1.53	−0.03	−0.74
14	Intention	5.04	1.62	−0.62	−0.22

Note: Salient beliefs [1 − 10] range from 1 to 49; TPB constructs [11–14] range from 1 to 7.

Toker & Baturay, 2016, p. 675) for the original model [$\chi^2_{342} = 237.53$, $p < .001$, $\chi^2/df = 4.80$, comparative fit index $CFI = .858$, standardized root mean square residual $SRMR = .089$, root mean square of approximation $RMSEA = .106$]. Inspection of the residuals and modification indices as recommended by Kline (2016) resulted in five additional paths: (1) *user advocacy* on attitude, (2) *awareness and priorities* to subjective norm, (3) *business opportunity*, (4) *product quality*, and (5) *self-perception as specialist* on perceived control. The resulting adjusted model (Fig. 2) showed good values for all fit indices [$\chi^2_{342} = 37.21$, $p = .055$, $\chi^2/df = 1.49$, $CFI = .985$, $SRMR = .027$, $RMSEA = .038$]. Additionally, a previously specified alternative model (Kline, 2016) was tested and rejected in favor of the presented version (for further details, see appendix B).

4.6.3. Model description

All paths, except *legal obligations* on subjective norm and *technical compatibility* on perceived control were significant. Attitude was found to be the most predictive antecedent for the intention to consider Web Accessibility. In turn, the salient beliefs *product quality* and *user advocacy* had the strongest influence on attitude. Subjective norm was found to be mainly influenced by *self-perception as specialist* and *user advocacy*. The most important salient beliefs for perceived control were *requirements conflict* and *awareness and priorities*. Overall, the three most beneficial salient beliefs observed were: (1) *user advocacy*, (2) *self-perception as specialist* and (3) *product quality*. The two most hindering salient beliefs were found to be: (1) *requirements conflict*, and (2) *personal effort*.

5. Discussion

5.1. Main salient beliefs

Overall, the main hindering salient beliefs *requirements conflict* and *personal effort* influenced the intention to consider Web Accessibility to a lesser extent than the main beneficial salient beliefs *user advocacy*, *self-perception as specialist* and *product quality*. Hence, the discussion focuses on the latter.

User advocacy emerged as the most important salient belief, influencing the formation of attitude as well as subjective norm regarding the consideration of Web Accessibility. An active demand for Web Accessibility by users can reduce misconceptions such as that people with disabilities do not use the web or that Web Accessibility serves too small of an audience (Ellcessor, 2014), which may be reflected in the influence of *user advocacy* on attitude. Adoption of the perspective of users with disabilities can be actively promoted within an organization, for instance by their direct involvement in the development process (Henry, 2007; Kalbag, 2017). This assures an understanding of the user needs at all stages, leading to better accessible solutions (Arrue, Vigo, & Abascal, 2008; Power, Freire, & Petrie, 2010) and increased motivation to pursue Web Accessibility by all stakeholders involved in the development process (Henry, 2006).

Self-perception as specialist showed significant influence on subjective norm as well as perceived control. This salient belief is comparable to main influences found in other studies such as pride and ambition (Velleman et al., 2017), the understanding that Web Accessibility is the right thing to do (Henry, 2006), or ethical considerations (Yesilada et al., 2014, 2012). Due to often self-acquired knowledge from various sources (Ellcessor, 2014), the orientation towards other web practitioners seems to have a special importance in the formation of subjective norms. Furthermore, *self-perception as specialist* also benefits perceived control, as it provides a strong motivation to face challenges, such as requirements conflicts or issues with technical compatibility. This may even lead to the exertion of pressure on employers to prioritize Web Accessibility (Oh & Chen, 2014).

Product quality positively influenced attitude as well as perceived

Table 4
Spearman correlations for all factors included in the model estimation.

#	Factor	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Personal effort													
2	Social responsibility	-.09												
3	Business opportunity	.02	.39***											
4	Product quality	-.11*	.55***	.47***										
5	Customer advocacy	.00	.37***	.42***	.48***									
6	Legal obligations	.05	.25***	.25***	.32***	.53***								
7	Self-perception as specialist	.05	.13*	.32***	.29***	.47***	.43***							
8	Awareness and priorities	.08	.23***	.37***	.32***	.50***	.45***	.47***						
9	Requirement conflicts	.23***	.04	-.07	.06	-.06	.01	.00	-.11					
10	Technical compatibility	.28***	-.10	.05	.00	.02	.09	.03	-.05	.39***				
11	Attitude	-.21***	.54***	.46***	.62***	.50***	.33***	.27***	.29***	.00	-.10			
12	Subjective Norm	.03	.27***	.39***	.41***	.57***	.46***	.57***	.54***	-.02	-.06	.48***		
13	Perceived Control	.06	.16**	.44***	.40***	.36***	.28***	.39***	.42***	-.18***	-.01	.36***	.55***	
14	Intention	-.11*	.41***	.44***	.55***	.52***	.40***	.41***	.41***	-.09	-.10	.65***	.63***	.55***

Note: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

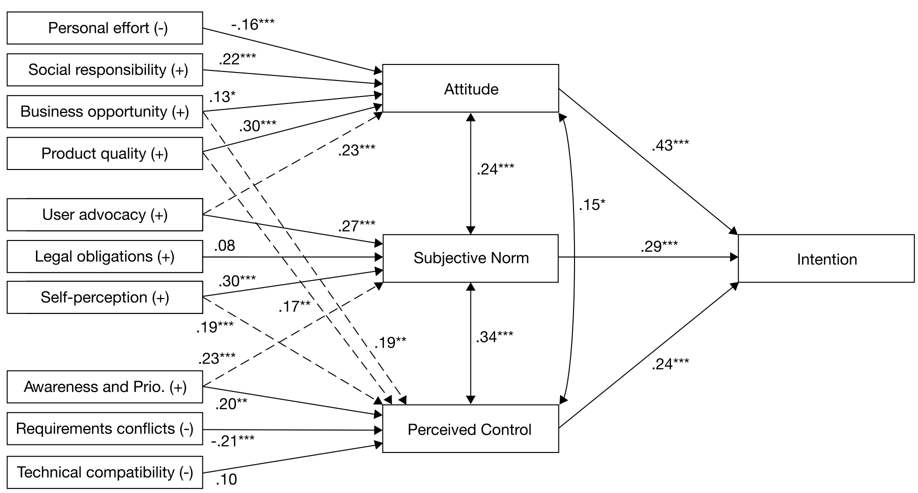

Fig. 2. Adjusted TPB Model after inspection of the residuals and modification indexes. Additional paths are indicated with dashed lines. *Note:* $^{*}p < .05$; $^{**}p < .01$; $^{***}.p < .001$

control. The intention to design better products was also found to be an important driver for Web Accessibility in previous findings (Leitner et al., 2016; Yesilada et al., 2012). This stands counter to prevalent misconceptions that consideration of Web Accessibility leads to boring and ugly solutions (Ellcessor, 2014; Henry, 2006), as well as to studies of adverse effects, such as the reduction of language complexity decreasing text liking and the intention to revisit a website compared to conventional variants (Schmutz, Sonderegger, & Sauer, 2019). Hence, it is important to highlight beneficial effects of Web Accessibility for all user groups (Schmutz et al., 2016; 2017a; 2017b), while potentially problematic aspects should be further addressed in research (e.g., Vollenwyder et al., 2018) to explore potential solutions and provide guidance for practice.

5.2. Limitations and future research

Overall, a majority of participants had a favorable attitude towards Web Accessibility. It is therefore possible that personal interest in Web Accessibility was especially high in the present sample. Consequently, salient beliefs such as *self-perception as specialist* may have received relatively more attention, while other beliefs may have been underestimated. Arguably, although participants were recruited from two different sources, a self-selection bias cannot be fully ruled out. Further research could address this issue with the application of other sampling strategies and by focusing on a more diverse sample, for instance by specifically including web developers with an unfavorable attitude towards Web Accessibility.

In their methodological recommendations, Fishbein and Ajzen (2010) propose conducting a follow-up study to assess whether participants followed through with their intention and performed the behavior of interest. Web development projects vary substantially in their size and duration, which makes it difficult to find an appropriate point in time for conducting such a follow-up study and led to the exclusion of this step in the present study. Further examination of this gap would allow the estimation of the relationship between intention and behavior, and evaluating the influence of limited resources as mediating factor (compare Fig. 1).

The influence of background factors is a frequently discussed issue in TPB research (Ajzen, 2011; Ajzen & Fishbein, 2005). While TPB outlines how salient beliefs may determine the intention and actual performance of a behavior, it does not specify the origins of these beliefs. Such background factors encompass basic demographic variables such as age, gender, and education. While it would require a larger and more specific sample, it would also be valuable to examine whether and to what extent different web practitioner roles judge the relative importance of influencing factors differently.

5.3. Implications for practitioners

The findings of the present study have several implications for web practitioners. First, although user-centered design methods are well-established in web development, users with disabilities are presently rarely involved in these processes (Henry, 2006). The high impact of *user advocacy* on Web Accessibility highlights the importance of including end users with a diverse range of abilities in the development process to provide accessible solutions. Such an involvement could be established in various forms, for instance with the introduction of a user community, an advisory board, or in conducting usability testings with specific user groups (for a practical introduction, see Henry, 2007). Such approaches also help promote awareness for Web Accessibility at all organizational levels (Urban & Burks, 2006). Further, the application of user-centered design methods in Web Accessibility can contribute to an improved usability and user experience for all user groups, as usability and Web Accessibility issues sometimes overlap (Petrie & Kheir, 2007). For instance, beneficial effects of Web Accessibility on improved performance and perceived usability for users with and without disabilities have been found previously (Schmutz et al., 2016; 2017a; 2017b). Therefore, the recommended involvement of users with disabilities in the development process could promote the intention to consider Web Accessibility, and represent a promising strategy to improve usability and user experience for all user groups.

Second, web practitioners' knowledge and skill of how to effectively work on Web Accessibility should be continuously supported, because it benefits their *self-perception as specialists*. For instance, organizations should invest in learning materials and training to establish solid Web Accessibility knowledge across the entire development process. Furthermore, sharing experiences regarding Web Accessibility with other web practitioners should be encouraged. Web practitioners occupying similar roles may face similar challenges and can exchange advice, build confidence, and develop good practices.

Third, with regards to *product quality*, the advantages of Web Accessibility should be emphasized in the development process. If benefits for all user groups are highlighted, Web Accessibility is much more likely to be considered. Furthermore, it can be argued that continuous consideration leads to a more enduring product (Leitner et al., 2016), preventing expensive retrofitting if Web Accessibility becomes a requirement later on (Urban & Burks, 2006). Finally, enhanced quality due to the implementation of Web Accessibility measures may provide a competitive advantage for a product (Kalbag, 2017).

6. Conclusion

The present work investigated the main salient beliefs influencing the intention to consider Web Accessibility. *User advocacy*, *self-perceptions as specialist* and *product quality* were identified as most important motivators. Hence, we recommend including users with a variety of abilities in the development process, inspiring confidence in web practitioners' personal role, and actively promoting Web Accessibility as a key attribute of product quality. We hope our research encourages web practitioners to further contribute to a web for everyone.

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Appendix

Appendix A. TPB Questionnaire

All items were answered on a 7-point-Likert scale from 1 (completely disagree) to 7 (completely agree). Salient beliefs were calculated by multiplication of the items in Table 5 (outcome of a salient belief) with their corresponding items in Table 6 (strength of a salient belief), resulting in a range from 1 to 49. Direct measures were calculated as arithmetic means of the two corresponding items presented in Table 7 (TPB direct measures), resulting in a range from 1 to 7.

Table 5
TPB questionnaire items to evaluate outcomes of the main salient beliefs.

Factor	TPB	Item
Personal effort	Attitude	The consideration of Web Accessibility in my next project makes my work more complex.
Social responsibility	Attitude	With the consideration of Web Accessibility in my next project, I can support other people.
Business opportunity	Attitude	The consideration of Web Accessibility in my next project is an opportunity to reach more clients with my work.
Product quality	Attitude	The consideration of Web Accessibility in my next project improves the quality of my work.
User advocacy	Subjective Norm	Users expect that I consider Web Accessibility in my next project.
Legal obligations	Subjective Norm	Legal obligations require that I consider Web Accessibility in my next project.
Self-perception as specialist	Subjective Norm	Most specialists in the same role as me consider Web Accessibility in their upcoming projects.
Awareness and priorities	Perceived Control	My employer's awareness and prioritization of this issue makes it easier for me to consider Web Accessibility in my next project.
Requirement conflicts	Perceived Control	Requirements of my employer (conflict with other requirements corporate identity guidelines, etc.) make it difficult for me to consider Web Accessibility in my next project.
Technical compatibility	Perceived Control	Technical constraints (frameworks, used components, etc.) make it difficult for me to consider Web Accessibility in my next project.
Limited resources	Actual Control	Lack of time and money makes it difficult for me to consider Web Accessibility in my next project.
Knowledge and skills	Background Factors	Lack of knowledge and skill make it difficult for me to consider Web Accessibility in my next project.

Table 6
TPB questionnaire items to evaluate strength of the main salient beliefs.

Factor	TPB	Item
Personal effort	Attitude	Complex tasks are unpleasant for me.
Social responsibility	Attitude	Supporting other people is pleasant for me.

(*continued on next page*)

Table 6 (*continued*)

Factor	TPB	Item
Business opportunity	Attitude	Reaching more clients is desirable to me.
Product quality	Attitude	Raising the quality of my work ist desirable to me.
User advocacy	Subjective Norm	Regarding Web Accessibility, I want to do what users expect from me.
Legal obligations	Subjective Norm	Regarding Web Accessibility, I want to be compliant with legal obligations.
Self-perception as specialist	Subjective Norm	Regarding Web Accessibility, I want to be like most of the specialists working in the same role like me.
Awareness and priorities	Perceived Control	It is likely that my next employer will have a high awareness and priority for Web Accessibility.
Requirement conflicts	Perceived Control	It is likely, that requirements of my employer (conflict with other requirements corporate identity guidelines, etc.) will make it difficult to me, to consider Web Accessibility in my next project.
Technical compatibility	Perceived Control	It is likely that technical constraints (frameworks, used components, etc.) will make it difficult for me to consider Web Accessibility in my next project.
Limited resources	Actual Control	It is likely, that I will not have the time and money necessary to consider Web Accessibility in my next project.
Knowledge and skills	Background Factors	It is likely, that I will not have the knowledge and skill necessary to consider Web Accessibility in my next project.

Table 7
TPB questionnaire items to evaluate direct measures.

TPB	Item
Attitude	The consideration of Web Accessibility in my next project would be pleasant for me.
Attitude	The consideration of Web Accessibility in my next project would be desirable for me.
Subjective Norm	Most people who are important to me approve of my consideration of Web Accessibility in my next project.
Subjective Norm	Most people in the same role as me consider Web Accessibility in their upcoming projects.
Perceived Control	The consideration of Web Accessibility in my next project is up to me.
Perceived Control	I am confident that I can consider Web Accessibility in my next project.
Intention	I intend to consider Web Accessibility in my next project.

Appendix B. Alternative Model

A previously specified alternative model without the TPB constructs attitude, subjective norm and perceived control was tested and rejected in favor of the model presented in the results section. All salient beliefs were directly linked to intention, which led to an unsatisfying fit [$\chi^2_{342} = 502.08$, $p < .001$, $\chi^2/df = 15.21$, comparative fit index $CFI = .418$, standardized root mean square residual $SRMR = .206$, root mean square of approximation $RMSEA = .204$].

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How to Use Plain and Easy-to-Read Language for a Positive User Experience on Websites

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Abstract. Plain Language and Easy-to-Read Language are two approaches to reduce language complexity, which are also applied in the context of Web Accessibility. While Easy-to-Read Language was specifically designed to meet the needs of people with cognitive and learning disabilities, benefits for users with a variety of abilities have been reported. However, studies have also found unintended side-effects on non-disabled users, such as reduced text liking and intention to revisit a website compared to variants in conventional language. The present study addresses this issue by testing two approaches combining conventional with Easy-to-Read Language against a Plain Language variant, as well as a control group in conventional language. In an online study, 308 non-disabled participants read three texts presented in one of the four language variants. Measurements of performance indicators as well as subjective responses show that Easy-to-Read language may be implemented without unintended side-effects.

Keywords: Plain Language · Easy-to-Read Language
User Experience

1 Introduction

Language complexity is an often-underestimated factor in Web Accessibility. Early research and development within Web Accessibility mainly focused on perceptibility and operability. In recent years, aspects that support understandability, such as content design, structure and wording, have gained increasing importance [1,2]. While understandability is often discussed in the context of cognitive and learning disabilities, benefits for users with a variety of abilities have been reported [3–6].

The Web Content Accessibility Guidelines 2.0 address language complexity in a rather broad sense: Unusual words (criterion 3.1.3) as well as abbreviations (criterion 3.1.4) should be explained, while the overall reading ability

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required to understand the text should not exceed lower secondary education (criterion 3.1.5). More specific recommendations to reduce language complexity are proposed with the concepts of *Plain Language* and *Easy-to-Read Language*. Both approaches differ regarding their formalisation and their intended audience. *Plain Language* has its roots in efforts to improve government information and focuses on clear and precise writing [7]. It is centred on the user's goals and tries to make the content easily scannable and understandable by avoiding long, convoluted sentences and jargon. There is no clearly defined target group, as writings in Plain Language aim at being understandable for as broad an audience as possible. *Easy-to-Read Language*, in contrast, was specifically designed to meet the needs of people with cognitive and learning disabilities [8]. However, Easy-to-Read Language also benefits a potentially larger audience, such as people with low language skills or auditory disabilities [1]. Texts in Easy-to-Read Language attempt to be as simple as possible. Guidelines include the use of very clear sentence structures, making only one statement per sentence and avoiding difficult words. Additional recommendations for optimal readability exist. Easy-to-Read Language is characterised by the rule to present one sentence per line, turning the text presentation into a list-form [9].

Research generally reports that Easy-to-Read Language benefits users with cognitive and learning disabilities [8]. However, studies have found unintended side-effects on non-disabled users [5,10]. While non-disabled users also seem to benefit from better text understanding, they prefer conventional language with regards to text liking. Further, their intention to revisit a website was reduced when Easy-to-Read Language was applied [10]. Importantly, these findings contrast recent studies that showed no drawbacks of implementing other Web Accessibility criteria [11]. Because non-disabled users arguably represent the main user base of most websites, practitioners are very sensitive to potential trade-offs and will not implement controversial recommendations [12]. Hence, further research is necessary to find solutions suitable for all user groups [1,5].

The present work addresses potential unintended side-effects by proposing a dynamic and a static approach for combining conventional with Easy-to-Read Language (see Sect. 2.2). The contribution is three-fold: (1) Different approaches for countering potential negative side-effects of reducing language complexity are tested in an experimental design. (2) Thanks to a collaboration with the Swiss Federal Railways, a real-world example of practical relevance is studied. (3) The theoretical and practical discourse about the application of Plain and Easy-to-Read Language on websites is advanced.

2 Method

2.1 Participants and Design

A total of 336 participants completed an online study. A priori power analysis suggested a minimum sample size of 280 participants. Recruitment was conducted by the recruiting-service TestingTime, targeting a balanced sample in terms of age and gender. Participants received a payment of 10 Swiss Francs (about 8.50 Euros) for completing the study. Twenty-eight participants were subsequently excluded from the sample: Seven participants indicated that they did not answer the questionnaire seriously, 14 participants completed the questionnaire in less than 10 min and one participant's response time exceeded one hour. Finally, 6 participants were excluded because they did not fully answer the cloze test to estimate their level of literacy.

In total, 308 non-disabled participants (age $M = 41.8$, $SD = 16.0$, range 18–79; 165 women, 140 men, 3 non-binary or not specified) were included in the analysis. On average, the study took 21 min ($SD = 8.5$ min) to complete. The study consisted of a one-factorial between-subjects design with four conditions. Experimental groups did not significantly differ with regards to age, gender distribution or literacy.

2.2 Materials

The selection of texts for the study was based on the experiences of call agents working in the contact centre of the Swiss Federal Railways, covering common questions by customers. For these topics, texts with a length of approximately 300–400 words (i.e., a reading time of about 2 min) were screened. Three text samples A (excerpt of terms of conditions), B (excerpt of privacy policy) and C (advertisement letter) were selected and subsequently translated by a professional translator into a Plain Language and an Easy-to-Read variant. The Easy-to-Read variant was translated according to the ruleset of the "Forschungsstelle Leichte Sprache" of the University of Hildesheim [9]. The translation was tested by four reviewers with cognitive disabilities. Based on the reviewers' qualitative feedback, the Easy-to-Read text was deemed adequate and accessible. Additionally, the texts were analysed with the German version of the Flesch-Reading-Ease formula [13], which provides a readability score ranging from 0 (very easy) to 100 (very difficult). This analysis showed a decrease of text difficulty for the translations compared to the original text in conventional language. Descriptives for all texts and variants are presented in Table 1.

Next, four variants of a website were prepared to present the texts: (1) A control group, where the original text was presented in *conventional* language. (2) A condition in *Plain Language* text. (3) A combination of the original text with a *dynamic presentation of the Easy-to-Read text* (ETR Dynamic). Specifically,

Table 1. Descriptives for all texts and language variants including word count and the Flesch-Reading-Ease score ranging from 0 (very difficult) to 100 (very easy).

	Conventional language		Plain Language		Easy-to-Read Language	
	Words	Flesch score	Words	Flesch score	Words	Flesch score
Text A	352	45	932	72	739	81
Text B	302	41	450	61	543	73
Text C	175	70	252	80		

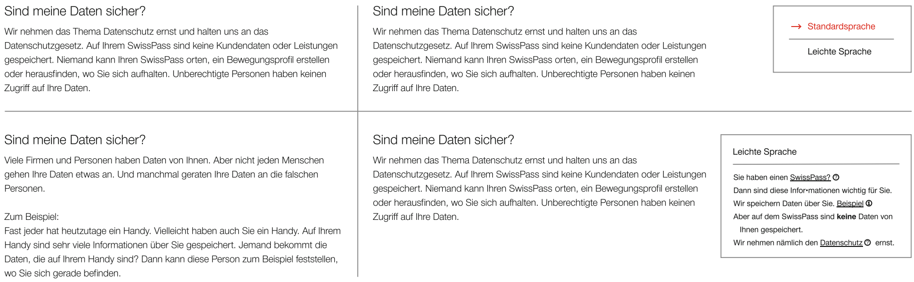

Fig. 1. Screenshot of all four conditions. Top Left: Conventional language. Bottom Left: Plain Language. Top right: ETR Dynamic. Bottom right: ETR Static.

participants had the option to actively adapt the text complexity for each paragraph. To do so, a language toggle was presented next to each paragraph, with the original text selected as default option. To provide participants the flexibility to read only certain parts of the text in Easy-to-Read Language, changes on a per paragraph basis were favoured over adapting the entire text. (4) A combination of the original text with a *static presentation of the Easy-to-Read text* (ETR Static), displayed in an additional box next to the original text. Screenshots of all four conditions are presented in Fig. 1.

For texts A and B, the visual design from the original website of the Swiss Federal Railways was recreated. All four conditions were identical in terms of website elements, such as pictures and the navigation bar. Text C was presented as an e-mail newsletter. It was assumed that e-mails have limitations with regards to the presentation of additional interactive elements. Therefore, only a variant in conventional and in Plain Language was created.

Finally, multiple choice and true/false statements were developed for measuring text understanding of texts A and B [10]. The study was then pre-tested with 10 participants (age M = 37.14, SD = 15.40, range 22–68; 3 women, 7 men), who were asked to provide detailed feedback regarding the presentation of the texts and the text understanding measurement.

2.3 Procedure

Participants were first asked to provide demographic information and complete a cloze test to estimate their literacy level [14]. All participants read all three texts. Each text was randomly presented in one of the four language conditions. Texts were presented in counterbalanced order. Participants could return to the questionnaire whenever they were ready to rate the text they had just read (see Sect. 2.4). Finally, participants had to indicate whether their responses were serious and had the opportunity to comment on the study.

2.4 Measures

Various performance indicators and subjective responses were measured. Performance indicators included: (1) reading time and (2) a score for text understanding. The score (maximum possible score 40 points) was calculated based on multiple choice questions and true/false statements. Additionally, in the Easy-to-Read Language conditions, the use of the language toggle was tracked.

Subjective responses included: (1) subjective comprehension ("How well did you understand the text on the website?"), (2) trust ("How trustworthy did you find the information on the website?") and (3) two items for text liking ("I like the style in which text on the website has been written", "The writing style of the text on the website is appealing.") that were adopted from [10]. All questions were answered on a 7-point Likert scale. (4) Perceived aesthetics was measured with the short version of the Visual Aesthetics of Websites Inventory (VisAWI, [15]). (5) The pragmatic (PQ) and hedonic quality (HQ) of the website was assessed with the short version of the AttrakDiff [16]. In the Easy-to-Read Language conditions, participants additionally rated the helpfulness of the Easy-to-Read text ("How helpful were the additional texts for your understanding?").

3 Results

3.1 Performance Indicators

Planned contrasts revealed that reading time differed significantly between conditions for text A. As shown in Table 2, participants spent significantly less time reading the conventional language condition compared to the experimental conditions ($F(1,\ 262) = 5.71$, $p < .05, \eta^2 = 0.017$). Texts B and C did not differ significantly in terms of reading duration. Text understanding did not differ between conditions and texts.

3.2 Subjective Responses

With regards to subjective comprehension, a Kruskal-Wallis test indicated significant differences between conditions for texts A ($\chi^2(3) = 19.27$, $p < 0.001, \eta^2 = 0.058$), B ($\chi^2(3) = 14.55$, $p < .01, \eta^2 = 0.043$) and C ($\chi^2(1) = 6.66$, $p < .01, \eta^2 = 0.020$). Conover-Imans's pairwise comparisons with a Holm correction for multiple comparisons revealed lower subjective comprehension for conventional language versus Plain Language for texts A ($p < .001, d = 0.79$), B ($p < .01, d = 0.52$), and C ($\chi^2 = 6.66$, $p < .01, \eta^2 = 0.020$). Further, Plain Language scored better on subjective comprehension compared to ETR Dynamic for texts A ($p < .01, d = 0.61$) and B ($p < .01, d = 0.64$).

In terms of pragmatic quality, planned contrasts showed significant differences between conditions for text A and text C. Conventional language scored lower compared to all experimental conditions for text A ($F(1,\ 262) = 5.83$,

$p < .05, \eta^2 = 0.011$) and text C ($t(270) = 2.02$, $p < .05, d = 0.25$). Further, higher PQ ratings were found for text A ($F(1, 262) = 4.68$, $p < .05, \eta^2 = 0.006$) for Plain Language compared to the Easy-to-Read conditions. Ratings for trust, text liking, perceived aesthetics and hedonic quality did not differ significantly between conditions and texts.

Table 2. Means and standard deviations for all dependent variables as a function of language conditions.

		Conventional	Plain	ETR Dynamic	ETR Static
Text A	Reading Time[a]	135.99 (85.77)	182.31 (122.88)	185.45 (179.28)	183.97 (164.42)
	Text Understanding	28.79 (5.40)	29.83 (5.13)	29.05 (5.57)	30.08 (6.82)
	Sub. Comprehension[b]	5.37 (1.37)	6.24 (0.76)	5.61 (1.27)	5.81 (1.11)
	Trust	5.75 (1.22)	5.92 (1.17)	5.94 (1.01)	5.89 (1.27)
	Text Liking	4.53 (1.40)	4.65 (1.75)	4.34 (1.58)	4.55 (1.55)
	VisAWI	4.94 (1.04)	4.98 (1.08)	4.66 (1.25)	4.95 (1.14)
	PQ[c]	4.80 (1.33)	5.48 (1.06)	4.91 (1.41)	5.25 (1.19)
	HQ	4.40 (1.15)	4.44 (1.17)	4.38 (1.26)	4.61 (1.11)
Text B	Reading Time	96.22 (46.91)	110.48 (65.63)	104.29 (51.57)	112.23 (56.34)
	Text Understanding	26.05 (4.38)	26.88 (4.26)	26.00 (4.75)	26.32 (4.20)
	Sub. Comprehension[b]	5.92 (1.28)	6.46 (0.78)	5.79 (1.27)	6.19 (0.79)
	Trust	5.76 (1.13)	5.75 (1.32)	5.70 (1.44)	5.96 (1.18)
	Text Liking	5.01 (1.26)	5.09 (1.38)	5.15 (1.21)	4.98 (1.56)
	VisAWI	4.94 (0.91)	4.94 (1.09)	5.15 (1.05)	5.03 (1.21)
	PQ	5.36 (1.06)	5.57 (1.09)	5.34 (1.14)	5.43 (1.04)
	HQ	4.69 (0.97)	4.74 (1.12)	4.85 (1.11)	4.78 (1.23)
Text C	Reading Time	63.62 (70.73)	63.85 (31.80)		
	Sub. Comprehension[b]	6.38 (0.82)	6.60 (0.75)		
	Trust	6.18 (0.89)	6.01 (1.19)		
	Text Liking	5.39 (1.24)	5.03 (1.65)		
	VisAWI	5.09 (1.10)	4.94 (1.21)		
	PQ[c]	5.59 (1.05)	5.83 (0.86)		
	HQ	4.99 (1.03)	4.88 (1.29)		

Note. [a] Reading Time for conventional language significantly shorter than in all other conditions.
[b] Subjective comprehension for Plain Language significantly higher than in all other conditions.
[c] Pragmatic quality for Plain Language significantly higher than in all other conditions.

3.3 Helpfulness of Dynamic and Static Easy-to-Read Texts

Most participants noticed the presence of the additional Easy-to-Read texts for text A (dynamic = 54.6%, static = 85.9%) and text B (dynamic = 61.9%, static = 81.2%), which was more pronounced in the static condition. Both Easy-to-Read variants were deemed moderately helpful for text A (dynamic M = 4.66, SD = 1.70; static M = 5.00, SD = 1.82) and text B (dynamic M = 4.97, SD = 1.55; static M = 4.89, SD = 1.65). In the dynamic condition, all participants had used the language toggle at least once for text A (toggle uses M = 3.12, SD = 2.51, range 1–14) and text B (toggle uses M = 3.17, SD = 1.95, range 1–7).

4 Discussion

Results show that the proposed approaches combining Easy-to-Read Language with conventional language did not result in the unintended side-effects on text liking reported in previous studies [5,10]. As most participants noticed the additional texts, these approaches seem to be discrete enough to prevent a negative impact on User Experience. However, whereas no negative effects on text liking or perceived aesthetics were found, no significant benefits for text understanding in the Easy-to-Read conditions were observed either. The moderate helpfulness ratings of the additional texts suggest that the information provided might not have been appropriate in the present situation or that the writing style did not appeal to users. Both factors may have reduced the active use of the additional Easy-to-Read texts. Further, as suggested by the longer reading time, too much text was perhaps presented at once, thus reducing the utility of the provided information. Nevertheless, it is important to note that the review group did rate the Easy-to-Read text as accessible. Hence, it is arguably more important to further improve the presentation of additional Easy-to-Read text for the needs of users with cognitive and learning disabilities. As long as there are no drawbacks for other users, a maximum of inclusion can be attained this way. Hence, it is essential to involve potential end users in the development process [2]. As all participants in the study used the language toggle at least once, this concept seems to work for non-disabled participants. It remains to be seen whether this also holds true for users with cognitive and learning disabilities, or if the static presentation or other solutions are preferable options.

For the Plain Language variant, multiple advantages compared to the conventional language text were found, which also applied for non-disabled users. The positive effects on subjective comprehension and pragmatic quality suggest that the Plain Language text was deemed more understandable and more suitable for users' needs. While this effect was merely subjective and did not translate into higher text understanding scores for the present sample, this might contribute to a better overall User Experience due to a positive perception of self-efficacy [17]. Perhaps, a combination of Plain Language and Easy-to-Read texts could make full use of the potential of the approaches discussed in the present paper.

5 Conclusion

The present study demonstrated that Easy-to-Read Language may be implemented without unintended side-effects. While positive effects for people with cognitive and learning disabilities could be retained, no negative effects on other users emerged. Further work should investigate an optimal implementation of the proposed approaches and strive to extend the positive effects for as broad an audience as possible.

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How compliance with web accessibility standards shapes the experiences of users with and without disabilities

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ABSTRACT

Benefits for all user groups is one of the most prominent motivations to provide accessible information and services on the web. Designing digital technologies in a more inclusive manner for users with sensory, motor, or cognitive impairments enhances their overall quality. In practice, work on web accessibility often relies on complying with standards. But whether standards lead to improved usability and a satisfying user experience for all user groups is controversial. The present study aims at deepening our understanding of how compliance with web accessibility standards shapes the experiences of both users with and without disabilities. In a randomised controlled experiment, 66 participants with visual impairments and 65 participants without visual impairments solved tasks on an online shop built with either low (NA) or high (AA) conformance to web accessibility standards. The results show no statistically significant effects on outcomes related to usability and user experience. However, analysis of open-ended answers suggests that participants with visual impairments reported more positive experiences, and participants without visual impairments fewer negative experiences while using the online shop conformant to web accessibility standards. We therefore recommend adopting a more differentiated perspective on what can be achieved through compliance with web accessibility standards and emphasise that conformance-based approaches should be complemented with user-centred and participatory design methods. Further, since most participants reported being experienced users and an online shop is often a familiar context, more research in other settings is required.

1. Introduction

Digital technologies have become pervasive and are indispensable in many domains of everyday life, ranging from daily social, economic, and political participation. This development presents opportunities to include users with diverse abilities, aptitudes, and attitudes (Horton and Quesenbery, 2014). Web accessibility supports diversity and inclusion by preventing the emergence of barriers to using the web that can result from sensory (e.g., vision, hearing), motor (e.g., tremor, limited use of hands), and cognitive (e.g., learning disabilities, attention deficits) impairments. It aims to provide useable information and services to as many people as possible (Kalbag, 2017) and contributes to the web's role in enabling and promoting equal participation in society (Henry, 2006).

One of web professionals' main motivations for considering web accessibility is that it enhances the overall quality of a product (Vollenwyder et al., 2019; Yesilada et al., 2012). In daily work on web accessibility, such efforts are often closely tied to compliance with given standards (Holliday, 2020). Frequently used manual and automated evaluation methods are based on web accessibility standards (Abou-Zahra, 2008). While standards are undeniably a solid foundation for creating accessible information and services on the web (Henry, 2006), there have been contrary findings regarding their impact on issues related to usability and user experience. A differentiated understanding

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of how an emphasis on compliance may affect the users is therefore an essential step in the process of considering web accessibility.

2. Background

2.1. Web accessibility and standards

Providing an accessible and useable web to people with disabilities has been considered essential since the early development of this technology (World Wide Web Consortium, 1997), but a widely used and agreed-upon definition of web accessibility has not been established (Petrie et al., 2015). According to an industry survey (Yesilada et al., 2012), the most popular definition is provided by the Web Accessibility Initiative (WAI), a subgroup of the World Wide Web Consortium (W3C). It states, "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" (Yesilada et al., 2012, p. 2). Whereas this description has a specific focus on people with disabilities, another prominent definition introduced by the International Standard Organisation (ISO) broadens the perspective to "the usability of a product, service, environment or facility by people with the widest range of capabilities" (International Organization for Standardization, 2019, Chapter 3.1). These examples show that the concept of web accessibility overlaps to some extent with the related concepts of usability and user experience. Whereas usability focuses on the objective (effectiveness, efficiency) and subjective (satisfaction) outcome of an interaction in a specific context, user experience introduces a holistic view (anticipated and actual use) and a primary focus on emotions (Sauer et al., 2020). All of these aspects have been taken into account as the concept of web accessibility has evolved (e.g., Aizpurua et al., 2016; Petrie and Kheir, 2007; Shneiderman, 2000).

The development of the theoretical perspective on web accessibility with influences related to usability and user experience, is also reflected in the practical work in the field. Early work on web accessibility was mainly technically oriented and concentrated on providing basic access to web technologies. Power et al. (2018) refer to this phase as "First Wave Inclusion", where the main goal was to enable users to obtain and enter information in an interactive system. Providing basic access is an ongoing task and the foundation for the accessibility of each emerging technology. It is achieved by offering alternate input modes (e.g., switch access that replaces interaction via touchscreen for users with limited dexterity in their hands) and by translating information into alternate output modalities (e.g., access by screen reader for users with visual impairments). The development of such approaches combined with the rise of web use led to the publication of the first Web Content Accessibility Guidelines (WCAG 1.0), which consists of a checklist meant to support developers with regard to what they should and should not include in their implementations on the level of code (Power et al., 2018; Chisholm et al., 1999). These guidelines were later revised and rearranged with the publication of the second edition of the Web Content Accessibility Guidelines (WCAG 2.0). To be more future-proof, the revised criteria were formulated in a technology-agnostic manner and arranged around the four pillars that technology should be (1) perceivable, (2) operable, (3) understandable, and (4) robust, which are referred to as the POUR principles (Caldwell et al., 2008; Power et al., 2012). They provide a foundation for a shared understanding regarding the needs of users with disabilities and serve as a reference for specific design decisions and as a standard for evaluations (Harper and Yesilada, 2008; Horton et al., 2015). These functions make the guidelines vital for creating accessible information and services on the web (Henry, 2006). Today, WCAG 2.0 is the de facto standard for web accessibility and is referenced in the policies of several countries worldwide (Waddell, 2006).

2.2. Web accessibility and usability

With the establishment of WCAG 2.0, less technically oriented aspects of web accessibility have also received more attention (Power et al., 2018). By addressing typical usability-related criteria such as effectiveness, efficiency, and satisfaction in a specified context of use, the revision of the guidelines adapted and introduced criteria that centre on user tasks rather than on providing basic access (International Organization for Standardization, 2019, Chapter 3.13). This shift in perspective is referred to as "useable accessibility" (Web Accessibility Initiative, 2016) or "Second Wave Inclusion" (Power et al., 2018). One example for such a transition can be found in criterion 1.3.2, which demands a "meaningful sequence" in content presentation (Caldwell et al., 2008). For instance, if a document presents text in multiple columns, the implementation should convey that the content flows from the top of a column to the bottom and then to the top of the next column. A user with a screen reader can then perceive the document in a meaningful sequence. This requires a design decision and implies that the reading sequence must be centred around users and their goals in a specific situation, rather than on just having a technologically sound implementation (Power et al., 2018). Accessibility experts widely agree that such usability-related considerations must be part of web accessibility (Yesilada et al., 2014).

A broader perspective on web accessibility also expands the potential group of users affected by a given criterion. For example, standards for minimal contrast may be indispensable for users with visual impairments to interact with a product, but users without a visual impairment can also benefit from such standards in many temporary states (e.g., tired eyes after a long work day) or situations (e.g., using a device in strong sunlight). These considerations reflect the fundamental idea that web accessibility should extend the use of a product to as many people as possible (Kalbag, 2017). This favourable attitude regarding web accessibility is a prevalent opinion among web professionals, who often state that increasing the overall quality of a product is one of the main motivations for considering web accessibility (Vollenwyder et al., 2019; Yesilada et al., 2012). Further, it is in line with related concepts such as design for all (e.g., Bendixen and Benktzon, 2015), inclusive design (e.g., Clarkson et al.) and universal design(e.g., Iwarsson and Ståhl, 2009), which emphasise the idea of designing artefacts that address users with a wide range of capabilities (Sauer et al., 2020).

However, to what degree the compliance with given standards is sufficient to provide useable accessibility for all user groups is not without controversy in research and practice. User evaluations of 16 websites based on WCAG 2.0 showed that a large part of the problems encountered are either not solved by the given criteria or not covered at all (Power et al., 2012). Further, the often technical perspective of WCAG 2.0 is criticised as not centred on actual user needs (Cooper et al., 2012; Pereira and Archambault, 2018; Rømen and Svanæs, 2011) and as difficult to evaluate (Brajnik et al., 2012, 2011). This contrasts with a series of studies by Schmutz et al. (2016, 2017b,a), who invited participants with and without impaired eyesight to test a municipality's website in three different conformance levels. They measured indicators related to usability and user experience such as task-completion time, perceived usability, and the perceived visual aesthetic. The findings in all the studies showed a stable beneficial effect of high conformance with web accessibility standards. This effect was observed to the same extent for users with and without disabilities. However, all three studies used the same website and similar tasks, which may limit the degree to which these results can be generalised to other contexts. In sum, current findings leave an unclear picture of whether compliance with web accessibility standards alone is sufficient to positively influence usability-related measures.

2.3. Web accessibility and user experience

A focus on providing basic access and on usability-related factors lays a solid foundation for the use of digital technologies. Work on these topics has enabled users with and without disabilities to achieve their goals in many everyday situations. Yet as digital technologies have become more prevalent in all corners of our lives, non-task-oriented aspects have also gained importance. Not only do the pragmatic qualities of a product receive attention but also the hedonic qualities, which address human needs such as stimulation, relatedness, competence, and popularity (Hassenzahl et al., 2010). Such considerations in relation to web accessibility are part of "accessible user experience" (Web Accessibility Initiative, 2016) or "Third Wave Inclusion" (Power et al., 2018), with its user experience-oriented understanding of access to digital technologies. Since web accessibility wants to include as many people as possible, user needs become more diverse. The goal is therefore to design experiences that are not identical but comparable in value and quality for each user (Swan et al., 2017).

As for usability-related criteria, issues related to user experience are also affected by web accessibility considerations. In this context, web professionals and other stakeholders express more reservations. For example, web accessibility standards are feared as being a constraint on innovation, which leads to boring products that cannot keep up with current trends (Ellcessor, 2014). Another prominent overlap of web accessibility and user experience is in the aesthetic of digital products. Often named fears refer to the restrictions on contrast and the use of colour, which are perceived as compromising the visual design (Mbipom and Harper, 2011; Petrie et al., 2004). On the contrary, investigations regarding the relationship between web accessibility and the visual aesthetic of websites show that visual cleanness correlates with accessible content, whereas other dimensions, such as expressive design, seem to be neither a benefit nor a barrier to web accessibility (Mbipom and Harper, 2011). Another field of interest related to user experience in the context of web accessibility is how language simplification on the web may be perceived by users with and without cognitive disabilities (Schmutz et al., 2019; Vollenwyder et al., 2018; Karreman et al., 2007). Applying the concept of easy-to-read language, which attempts to be as simple as possible, results in improvements on some performance measures for all user groups but also decreased liking of the text and reduced intention to revisit a website for users with no identified cognitive disabilities. However, it is important to note that easy-to-read language was explicitly designed to meet the needs of people with cognitive impairments and was not intended to be a substitute for conventional language (Fajardo et al., 2013).

Studies exploring the impact of compliance with web accessibility standards on user experience are rarely available. Aizpurua et al. (2015) invited eleven blind participants to interact with a selection of websites that conformed with standards to various degrees. They concluded that compliance does not always correspond with users' actual perception of web accessibility and that factors such as prejudices, memories, expectations, and confidence in a website play an important role. Further, the authors also investigated how perceived web accessibility correlates with measurements of pragmatic and hedonic qualities (Aizpurua et al., 2016) and proposed applying such measures as a proxy to estimate conformance to web accessibility standards. Other studies have included measures related to user experience in experimental setups that compare conformant with non-conformant websites. Findings have shown a positive influence on the scales for affect, the aesthetic, and user experience (Schmutz et al., 2017b) as well as on mood (Pascual et al., 2014b) for users with visual impairments. Positive effects on mood have also been reported for users with hearing (Pascual et al., 2014a) and motor (Pascual et al., 2015) impairments. As for outcomes related to usability, study designs that included nondisabled participants (Schmutz et al., 2017b; Pascual et al., 2014b) have shown that this effect on experience is not only limited to users with disabilities but also benefits users without disabilities. All in all, the majority of current findings have ascertained a positive influence from compliance with web accessibility standards on measures related to user experience.

2.4. Aim of the study

As summarised above, the current research does not give a consistent answer as to whether the positive effects from compliance with web accessibility standards can be expected for outcomes related to usability and user experience. Despite this uncertainty, the most predominantly used evaluation methods for web accessibility rely on compliance with standards (Sauer et al., 2020). For example, expert-based manual testing (Abou-Zahra, 2008), barrier walkthroughs (Yesilada et al., 2009), and automated testing (Vigo et al., 2013) use given standards as their foundation. Further, it has become a common goal for organisations to obtain some form of label or certification from external evaluators to document their efforts in providing accessible information and services. Again, such certification processes are heavily dependent on the frame provided by web accessibility standards (Abou-Zahra, 2008). Although it is not a new demand to focus on the user perspective while working on web accessibility (e.g., Cooper et al., 2012; Henry, 2007; Karreman et al., 2007), the outlined overemphasis on standard conformance has become a common complaint by web professionals. In the worst case, web accessibility is experienced as a meaningless box-ticking exercise (Holliday, 2020; Oswal, 2019) that leads to poor implementations for all users.

The present study aims to contribute to a more differentiated understanding of how compliance with web accessibility standards shapes the experiences of users. Participants with and without visual impairments interacted in a randomised controlled experiment with either a conformant or a non-conformant version of a website. The materials used took the requirements of WCAG 2.0 into account. To complement previous studies, the materials were situated in the context of an online shop. The study design made it possible to explore the impact of compliance with web accessibility standards on outcomes related to usability and user experience.

3. Method

3.1. Participants and design

3.1.1. Sampling procedure

A total of 167 participants completed the online study. We targeted a sample size comparable to previous studies that reported significant group differences for compliant and non-compliant websites (see Schmutz et al., 2017b,a). Invitations were sent via three ways. (1) The study was advertised over various newsletters and mailing lists across Switzerland specifically targeting audiences with visual impairments. Further, (2) the affiliated institute's participant pool and (3) the recruiting service TestingTime[1] were used. As an incentive for the first two channels, participants could take part in a lottery for three gift vouchers of 30 Swiss Francs (about 27 Euros), while participants via TestingTime received a payment of 7 Swiss Francs (about 6.50 Euros).

3.1.2. Data cleaning

In total, 36 participants were subsequently removed from the sample. The applied criteria followed recommendations for data quality in online surveys (Brühlmann et al., 2020; Curran, 2016). Twenty-six participants were removed for using a smartphone to complete the study, even though the instructions stated to use a desktop or laptop computer. One participant declared that they did not answer the study seriously and that their data should not be used for the main analysis. Three participants were removed after we screened open-ended answers for obviously careless responses, such as the use of random words or copying a single answer. One participant was removed because of a response time that exceeded 90 min. Four participants were removed because their task completion time was below or above three standard deviations from the mean. Finally, one participant was removed because of a LongString Index that indicated that more than half of their questionnaire answers in a row were identical.

[1] https://www.testingtime.com/en

Table 1
Matching variables divided into the experimental conditions user group (impaired eyesight, unimpaired eyesight) and conformance with web accessibility standards (NA = low conformance, AA = high conformance).

	Impaired eyesight		Unimpaired eyesight		Total	
	Level NA	Level AA	Level NA	Level AA	Level NA	Level AA
N	29	37	35	30	64	67
Age (SD)	36.3 (15.2)	39.3 (14.4)	38.4 (11.1)	40.5 (11.5)	37.5 (13.1)	39.9 (13.1)
Computer experience (SD)	6.0 (0.9)	6.1 (0.9)	6.0 (0.9)	6.1 (1.0)	6.0 (0.9)	6.1 (0.9)
Web experience (SD)	6.2 (0.9)	6.3 (0.9)	6.0 (0.9)	6.1 (1.0)	6.1 (0.9)	6.2 (0.9)

3.1.3. Sample description

The study employed a 2 × 2 between-subjects design with the user group (impaired eyesight, unimpaired eyesight) and conformance to web accessibility standards (NA = low conformance, AA = high conformance) as independent variables.

A total of 131 participants (age $M = 38.7$, $SD = 13.1$, range 18–77; 63 women, 65 men, 3 non-binary or not specified) was included in the main analysis. An overview is presented in Table 1. Two groups of participants, one with visual impairments ($N = 66$) and without (65), formed the sample. Participants with visual impairments were required to have a maximum visual acuity of 0.3 (World Health Organization WHO, 2019). In this group, people with reduced eyesight ($N = 15$, visual acuity under 0.3), people with severe visual impairments (9, visual acuity under 0.05), people considered to be blind (1, visual acuity under 0.02) and people considered to be fully blind (15) took part in the study. Information on participants' eyesight was self-reported and no vision tests were conducted. As digital assistive technologies, participants used screen magnifiers (22, 33.3% of the participants with visual impairments), screen readers (17, 25.8%), screen readers combined with a screen magnifier (7, 10.6%), and screen readers combined with a braille board (5, 7.6%). On average, the study took 22 min ($SD = 13.5$, range 4.5–75) to complete. High self-rated experience with computers in general ($M = 6.1$, $SD = 0.9$) and with using websites in particular ($M = 6.2$, $SD = 0.9$) was reported (both 7-point Likert scale, 1 = very low, 7 = very high). About two-thirds of the participants ($N = 78$, 59.5%) were recruited via newsletters, mailing lists, and the affiliated institute's participant pool, whereas the other third (53, 40.5%) participated via the recruiting service TestingTime.

Age, gender, self-rated experience with computers and with using websites were tested statistically for differences between the experimental groups. No significant differences were found ($p > .05$ for all variables). Additional analyses were conducted for participants who dropped out of the study midway and who were not included in the main sample (N = 65). Only participants that interacted for at least 10 s with the study before dropping out were analysed ($N = 61$). Participant dropout was not more frequent in a particular condition or user group ($p > .05$ for all experimental conditions).

3.2. Materials

3.2.1. Websites and tasks

An online shop for organically produced vegetables was used as stimuli for the present study. Three reasons led to this choice: (1) online shops are reported among the most problematic services regarding web accessibility (Heim et al., 2020); (2) they are a common type of website and permit a selection of tasks well suited for the study demands; and (3) they complement previous studies that focused on websites for restaurants (Aizpurua et al., 2015, 2016), tourist information (Pascual et al., 2014b), mobile-phone companies (Petrie and Kheir, 2007), leisure centres (Schmutz et al., 2019), and municipal services (Schmutz et al., 2016, 2017a,b). The online shop in the present study offered a wide range of organically produced vegetables that were organised into various categories and described with details about their origin and season. Further, the website provided information about the terms and conditions and some background information about the farm that (virtually) produced the vegetables. It was assumed that the overall theme of sustainable and healthy nutrition is of importance to many people, which led us to choose this type of online shop. We prepared two versions of the online shop, one with low conformance (NA) to web accessibility standards and one with high conformance (AA). A version with basic conformance (A) was not considered because most legal obligations require level AA, and previous findings have not shown significant differences between level NA and A, nor between level A and AA (Schmutz et al., 2016, 2017b). As can be seen on the screenshots presented in Fig. 1, the conformant condition featured higher contrasts between text and background, clearer indication of the navigation state, and a more visible keyboard focus. Further, there were various differences that are not perceivable on a screenshot, such as coherent heading structures, alternative texts for images, and clear tab orders. We only altered aspects required by WCAG 2.0 (e.g., contrast and link descriptions), while other characteristics of the online shop (e.g., text content or pictures) remained identical in both conditions. Manipulations applied by Schmutz et al. (2016, see section"Website Manipulation"), were used as inspiration for the present study but adapted and extended for the online shop context. In total, 21 criteria were manipulated. A detailed description is provided in the Appendix. After creating the websites, we chose three tasks for the participants that included typical activities on an online shop. The tasks are described in Table 2.

To ensure realistic manipulations, both versions of the online shop were tested and discussed in a workshop with experts from the foundation Access for all,[2] a Switzerland-based non-profit organisation offering training, reviews, and certifications for web accessibility. Additionally, an automated evaluation using the Web Accessibility Evaluation Tool (WAVE[3]) was run on the home, product, product detail, information, and checkout pages. This test showed a total number of 48 errors for the low-conformance condition and 2 errors for the high-conformance condition. The complete study was then pretested by three blind participants. Besides the manipulations, the study setting itself, including the online survey tool, was also tested and deemed accessible.

3.2.2. Quantitative measures

Performance was measured by evaluating the task completion rate (%) according to the criteria defined in Table 2 and by tracking the time spent on the online shop as the task completion time (seconds). Subjective measures were assessed after each task and after the completion of all the tasks. After each task, participants were asked to provide an estimate of whether they had or had not succeeded (perceived task success; nominal scale with yes, no, do not know). Further, satisfaction after completing the task was assessed with the After Scenario Questionnaire (ASQ; Lewis, 1995). After the completion of all the tasks, additional subjective measures were assessed. To allow for comparisons, the selection of questionnaires was kept similar to previous studies in the field (see Schmutz et al., 2016, 2017a,b). The German versions of four measures were used. (1) Perceived usability was evaluated with the Website Analysis and MeasureMent Inventory (WAMMI; Kirakowski et al., 1998), whereas the standard 5-point scale was replaced with a 7-point scale for a consistent response format;

2 https://www.access-for-all.ch/en

3 https://wave.webaim.org

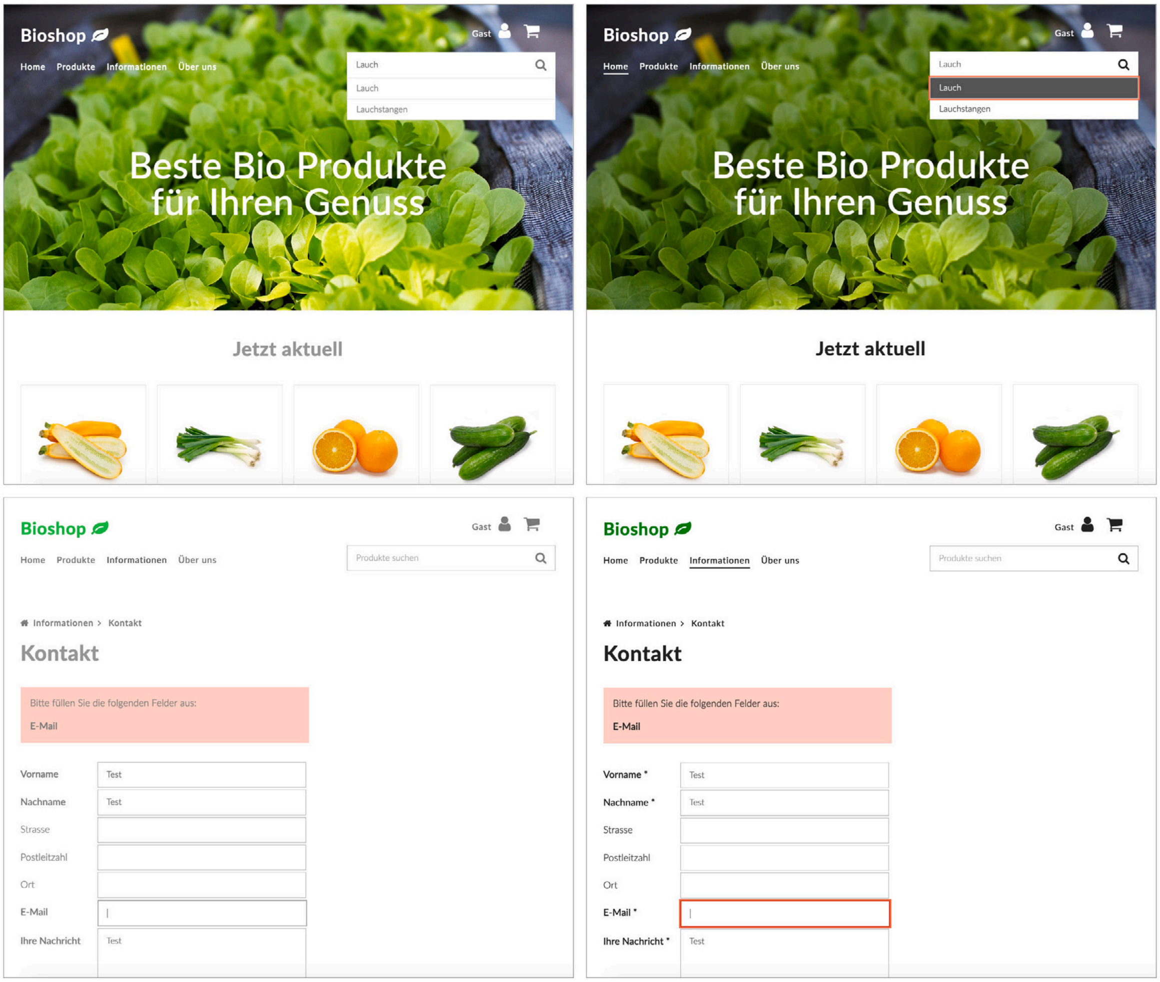

Fig. 1. Screenshots of the online shop used in the study. Top left: Home page with low conformance (NA) while searching for leeks. Top right: Home page with high conformance (AA). Bottom left: Contact form with low conformance while sending a request. Bottom right: Contact form with high conformance.

Table 2
Task descriptions.

Task	Description
1	Placement of an order on the online shop. Four items had to be found and added to the shopping cart, and the payment process had to be started. The task was successful if the correct items in the demanded amount had been added to the shopping cart when the checkout process was started.
2	Retrieval of information. Information regarding order closing times had to be found on the website. The task was successful if the correct time was reported.
3	Communication via contact form. A question had to be asked through the contact form of the shop. The task was successful if a message was sent from the contact form; the exact content of the message was not rated.

(2) the perceived aesthetic was measured with the short version of the Visual Aesthetics of Websites Inventory (VisAWI; Moshagen and Thielsch, 2013); (3) pragmatic and hedonic quality were rated with the short version of AttrakDiff2 (Hassenzahl and Monk, 2010); and (4) the likelihood to recommend the online shop was estimated by using the Net Promoter Score (NPS; Reichheld, 2003).

3.2.3. *Qualitative measures*

After the completion of each task and after the questionnaire section with subjective measures, participants were given the option to leave an open-ended comment ("If you would like to comment on this task (difficulties, uncertainties, etc.), please leave us a message".). Additionally, an open-ended question regarding overall difficulties with the website was included after the completion of all the tasks ("Have you encountered any obstacles while using the website? If so, please describe".). In total, we received 330 comments, sometimes describing multiple experiences. Responses were analysed with a qualitative content analysis (Flick et al., 2004). Following the definitions by Sauer et al. (2020), all reported experiences were assessed regarding their relation to web accessibility, usability, or user experience and their connotation with either positive or negative affect (see Table 3 for examples). Experiences that were not assignable to one of the concepts were analysed in a "not assignable" category, whereas experiences that were solely related to the study materials itself (e.g., comments regarding the survey tool, the pricing of the articles, etc.) were not included in the analysis. Sentences formed the smallest coding units and could be coded into multiple categories. The first author coded all open-ended answers. To ensure inter-rater reliability, a second independent

Table 3
Coding examples for open-ended answers.

Code	Affect	Example
Accessibility	Positive	"Could zoom in on the page well". (P125, NA condition, impaired eyesight)
	Negative	"The buttons to add a product to the shopping cart are missing labels". (P2, NA condition, impaired eyesight)
Usability	Positive	"One can find everything very quickly, read it clearly, and quickly order it". (P229, AA condition, impaired eyesight)
	Negative	"At first I couldn't find the vegetables that weren't on the start page. It took me a while to realise that there was a search field at the top". (P212, NA condition, impaired eyesight)
User experience	Positive	"I felt comfortable on the site and was able to read everything without a problem". (P204, AA condition, impaired eyesight)
	Negative	"The layout is professional. – Yes, but also a bit boring". (P17, AA condition, unimpaired eyesight)
Not assignable	Positive	"It was ok". (P224, NA condition, impaired eyesight)
	Negative	"I did not complete the order". (P111, NA condition, impaired eyesight)

coder coded a subset of 110 (33%) randomly selected comments. A substantial inter-rater agreement was achieved (Cohen's κ = .67), in line with Landis and Koch's recommendations (1977).

3.2.4. Manipulation check

In order to validate the experimental manipulation, an item asking for an accessibility rating ("Please rate the online shop according to its accessibility".; 1 = less accessible than other online shops, 7 = more accessible than other online shops) was included after the completion of all tasks. Participants unfamiliar with the term accessibility had the option not to answer. Since the website was specifically created for the present study, this item was used to estimate the external validation of the prepared materials, as well as to check for realistic manipulations. Reasonable experimental conditions would imply that participants rate the low-conformance (NA) version and the high-conformance (AA) version in a medium range in comparison to the quality of other typical online shops they have used in the past and therefore indicate authentic materials. Further, ratings between the two versions should not differ significantly, since this would indicate an unrealistic downgrade with barriers that would only appear if somebody intentionally breaks web accessibility. A comparable item was applied in a previous study (Schmutz et al., 2016). Further, open-ended answers were screened for accounts regarding the realism of the website and for unintended effects, such as technical problems with the website or the questionnaire.

3.3. Procedure

3.3.1. Study procedure

After informed consent was obtained, participants were asked to provide demographic information, to specify their eyesight, and, if applicable, to declare their setup of assistive technologies. Further, a self-rating of experience with computers ("How do you rate your experience with using computers?") and with the web ("How do you rate your experience with using the web?") was collected. Participants were then randomly assigned to the low-conformance (NA) condition or the high-conformance (AA) condition and asked to solve three typical tasks on an online shop as described in Table 2. The presentation of the tasks was counterbalanced to avoid order effects. For each task, participants were forwarded to the prototype of an online shop and returned to the questionnaire after solving or cancelling the task by choice. No login was required to access the online shop. The measurement of the task completion time started with the forwarding and ended with the return. No time limit was given. Task completion rate and completion time were automatically tracked during this procedure. A short questionnaire followed each task, and a longer questionnaire completed the study (see Section 3.2.2).

3.3.2. Missing data

For the ASQ, WAMMI, and VisAWI, participants were given the option to respond with "don't know" for a single item. This led to a total of 3.2% of missing data for these scales. To maintain as much information as possible, it was decided to impute the missing data. A visualisation of the data showed no noticeable patterns, and we assumed the data were missing at random. Expectation maximisation with age, gender, disability, experience with computers, and experience with websites as related variables was used to impute the missing data. The missing data were analysed using the naniar package (v0.6.1; Tierney et al., 2021), and the Amelia package (v1.8.0; Honaker et al., 2021) was used for data imputation.

4. Results

4.1. Manipulation check

Participants with visual impairments (number of ratings = 54, 81.8% of the sample) rated the low-conformance version (M = 5.58, SD = 1.47, 95% CI [4.96, 6.20]) as well as the high-conformance version (M = 5.37, SD = 1.43, 95% CI [4.83, 5.90]) in a medium range in comparison to the quality of other online shops they had used in the past (1 = less accessible than other online shops, 7 = more accessible than other online shops). Ratings between the versions did not differ significantly ($t(49)$ = 0.54, p = .588). Similar results were reported by participants without visual impairments (number of ratings = 38, 58.5% of the sample) for the low-conformance version (M = 5.24, SD = 1.37, 95% CI [4.61, 5.86]) and the high-conformance version (M = 4.94, SD = 1.14, 95% CI [4.35, 5.53]), but no significant difference between the versions was found ($t(36)$ = 0.73, p = .472). These results indicate that the used materials were perceived as comparable to an existing online shop and that the manipulations were not so extreme as to implement an unrealistic downgrade.

4.2. Quantitative measures

No significant differences were found for all the measures as a function of conformance to web accessibility standards. The user group and the interaction between conformance and the user group also did not exhibit any significance. The results of all the performance and subjective measures are presented in Table 4. As the use of various types of assistive technologies strongly influences how users navigate the web, we additionally analysed participants mainly using screen readers (N = 29, including combinations with magnifiers and braille boards) and participants mainly using screen magnifiers (22). Again, none of the measures did differ significantly for conformance with

Table 4
Results of performance and subjective measures.

	Level NA			Level AA		
Task completion rate (in %)						
	Mean	SD	Median	Mean	SD	Median
Impaired eyesight	66.7	33.3	66.7	73.9	34.4	100
Unimpaired eyesight	77.1	26.5	66.7	65.6	30.9	66.7
Total	72.4	30	66.7	70.1	32.9	66.7
Task completion time (in seconds)[1]						
	Mean	SD	Median	Mean	SD	Median
Impaired eyesight	81	57.8	63	103	53.5	97
Unimpaired eyesight	82	34.2	75.5	82.3	46.4	69.5
Total	81.6	45.3	69	93.5	51	85
Perceived task success (in %)						
	Mean	SD	Median	Mean	SD	Median
Impaired eyesight	93.1	20.7	100	95.5	14	100
Unimpaired eyesight	98.1	7.9	100	96.7	13.4	100
Total	95.8	15.1	100	96	13.6	100
Task satisfaction (ASQ, 1-7)						
	Mean	SD	Median	Mean	SD	Median
Impaired eyesight	4.9	2.3	6	5.2	2.2	6
Unimpaired eyesight	5	2	5.7	5.3	1.7	5.3
Total	4.9	2.1	6	5.2	2	6
Perceived usability (WAMMI, 1-7)						
	Mean	SD	Median	Mean	SD	Median
Impaired eyesight	5.5	1.4	5.8	5.4	1.4	6
Unimpaired eyesight	5.6	1.4	5.8	5.2	1.2	5.3
Total	5.5	1.4	5.8	5.3	1.3	5.9
Visual aesthetic (VisAWI, 1-7)[2]						
	Mean	SD	Median	Mean	SD	Median
Impaired eyesight	5.7	1.4	6	5.8	1.4	6
Unimpaired eyesight	5.6	1.6	6	4.8	1.3	4.9
Total	5.6	1.5	6	5.3	1.4	5.8
Pragmatic quality (AttrakDiff, 1-7)						
	Mean	SD	Median	Mean	SD	Median
Impaired eyesight	5.8	1.3	6	5.9	1.1	6.2
Unimpaired eyesight	6	1.2	6.2	5.6	1.2	5.8
Total	5.9	1.2	6.1	5.8	1.2	6
Hedonic quality (AttrakDiff, 1-7)						
	Mean	SD	Median	Mean	SD	Median
Impaired eyesight	5.1	1.4	5.2	5.1	1.3	5
Unimpaired eyesight	5	1.3	5	4.4	1	4.5
Total	5	1.3	5.1	4.8	1.2	4.8
Likelihood to recommend (NPS, total score of -100% to +100%)						
Impaired eyesight	10.3			21.6		
Unimpaired eyesight	-14.3			-30		
Total	-3.1			-1.5		

[1] Only successful attempts were used to compare task completion times.
[2] Fully blind participants were not asked for their ratings regarding the visual aesthetic.

web accessibility standards. The results focusing on the used assistive technologies are presented in Table 5.

Task completion rate. No significant differences in task completion as a function of conformance to web accessibility standards were found ($F(1, 127) = 0.17$, $p = .683$, partial $\eta^2 = .001$, 90% CI[0.00, 0.03]). Nor were significant differences found for the user group ($F(1, 127) = 0.03$, $p = .874$, partial $\eta^2 < .001$, 90% CI[0.00, 0.01]) or for the interaction between conformance and the user group ($F(1, 127) = 2.90$, $p = .091$, partial $\eta^2 = .022$, 90% CI[0.00, 0.08]).

Task completion time. Only successful attempts were used to compare task completion times. Results did not differ significantly for conformance ($F(1, 116) = 1.84$, $p = .178$, partial $\eta^2 = .016$, 90% CI[0.00, 0.07]), the user group ($F(1, 116) = 1.31$, $p = .255$, partial $\eta^2 = .011$, 90% CI[0.00, 0.06]), or the interaction between conformance and the

Table 5
Results of performance and subjective measures of participants mainly using screen readers ($N_{\text{Level NA}} = 12$, $N_{\text{Level AA}} = 17$) and participants mainly using screen magnifiers ($N_{\text{Level NA}} = 11$, $N_{\text{Level AA}} = 11$).

Task completion rate (in %)						
	Level NA			Level AA		
	Mean	SD	Median	Mean	SD	Median
Screen Reader	75	32.2	83.3	68.6	39.9	100
Screen Magnifier	60.6	36	66.7	72.7	36	100
Total	68.1	34.1	66.7	70.2	37.8	100
Task completion time (in seconds)						
	Level NA			Level AA		
	Mean	SD	Median	Mean	SD	Median
Screen Reader	73.8	69.7	56	110.5	65.6	102.5
Screen Magnifier	86.8	53.6	70	114.2	44.8	104.5
Total	79.7	61.7	59	112	56.7	102.5
Perceived task success (in %)						
	Level NA			Level AA		
	Mean	SD	Median	Mean	SD	Median
Screen Reader	94.4	13	100	94.1	17.6	100
Screen Magnifier	90.9	30.2	100	93.9	13.5	100
Total	92.8	22.4	100	94	15.9	100
Task satisfaction (ASQ, 1-7)						
	Level NA			Level AA		
	Mean	SD	Median	Mean	SD	Median
Screen Reader	5.1	2	6	4.9	2.1	6
Screen Magnifier	4.4	2.6	6	5.1	2.2	6.3
Total	4.8	2.3	6	5	2.1	6
Perceived usability (WAMMI, 1-7)						
	Level NA			Level AA		
	Mean	SD	Median	Mean	SD	Median
Screen Reader	5.5	0.9	5.6	5.3	1.4	6
Screen Magnifier	5.6	1.6	6.4	5.5	1.6	6
Total	5.5	1.2	5.8	5.4	1.4	6
Visual aesthetic (VisAWI, 1-7)						
	Level NA			Level AA		
	Mean	SD	Median	Mean	SD	Median
Screen Reader	6	0.6	6	6.1	0.9	6.2
Screen Magnifier	6	1.2	6.5	5.7	1.5	6
Total	6	0.9	6	5.9	1.2	6.2
Pragmatic quality (AttrakDiff, 1-7)						
	Level NA			Level AA		
	Mean	SD	Median	Mean	SD	Median
Screen Reader	5.6	0.8	5.6	5.6	1.1	6
Screen Magnifier	5.8	1.9	6.8	6	1.2	6.8
Total	5.7	1.4	6	5.8	1.1	6
Hedonic quality (AttrakDiff, 1-7)						
	Level NA			Level AA		
	Mean	SD	Median	Mean	SD	Median
Screen Reader	4.8	1	4.9	5	1.2	4.5
Screen Magnifier	5.5	1.7	6.5	5.5	1.2	5.2
Total	5.1	1.4	5.2	5.2	1.2	5
Likelihood to recommend (NPS, total score of -100% to +100%)						
	Level NA			Level AA		
Screen Reader	25			17.7		
Screen Magnifier	9.1			18.2		
Total	17.4			17.9		

[1] Only successful attempts were used to compare task completion times.
[2] Fully blind participants were not asked for their ratings regarding the visual aesthetic.

user group ($F(1,116) = 1.51$, $p = .221$, partial $\eta^2 = .013$, 90% CI[0.00, 0.07]).

Perceived task success. The perception of task success did not differ significantly for conformance ($F(1,127) = 0.55$, $p = .459$, partial $\eta^2 = .004$, 90% CI[0.00, 0.04]) or the user group ($F(1,127) = 3.53$, $p = .062$, partial $\eta^2 = .027$, 90% CI[0.00, 0.09]), and no significant interaction between conformance and the user group ($F(1,127) = 1.94$, $p = .166$, partial $\eta^2 = .015$, 90% CI[0.00, 0.07]) was found.

Task satisfaction. Task satisfaction was measured with the After Scenario Questionnaire (ASQ). We found no significant differences in task satisfaction as a function of conformance to web accessibility standards ($F(1,127) = 0.65$, $p = .421$, partial $\eta^2 = .005$, 90% CI[0.00, 0.05]). There were also no significant differences for the user group ($F(1,127) = 0.23$, $p = .631$, partial $\eta^2 = .002$, 90% CI[0.00, 0.03]) or for the interaction between conformance and the user group ($F(1,127) = 0.00$, $p = .987$, partial $\eta^2 < .001$, 90% CI[0.00, 0.00]).

Perceived usability. Perceived usability was measured with the Website Analysis and MeasureMent Inventory (WAMMI; $\alpha = .95$, $\omega_u = .96$, 95% CI[0.94,0.97]). The ratings for perceived usability did not differ significantly for conformance ($F(1,127) = 0.46$, $p = .500$, partial $\eta^2 = .004$, 90% CI[0.00, 0.04]) or for the user group ($F(1,127) = 0.10$, $p = .758$, partial $\eta^2 = .001$, 90% CI[0.00, 0.02]), and no significant interaction between conformance and the user group ($F(1,127) = 0.53$, $p = .470$, partial $\eta^2 = .004$, 90% CI[0.00, 0.04]) was found.

Visual aesthetic. The visual aesthetic was measured with the Visual Aesthetics of Websites Inventory (VisAWI; $\alpha = .94$, $\omega_u = .94$, 95% CI[0.92, 0.97]). Fully blind participants were not asked for their rating regarding the visual aesthetic. We did not find a significant difference for the visual aesthetic as a function of conformance ($F(1,121) = 1.67$, $p = .199$, partial $\eta^2 = .014$, 90% CI[0.00, 0.07]), of the user group ($F(1,121) = 3.86$, $p = .052$, partial $\eta^2 = .031$, 90% CI[0.00, 0.10]), or of the interaction between conformance and the user group ($F(1,121) = 3.03$, $p = .084$, partial $\eta^2 = .024$, 90% CI[0.00,0.09]).

Pragmatic quality. The pragmatic quality was measured with the pragmatic quality scale of the AttrakDiff2 ($\alpha = .89$, $\omega_u = .89$, 95% CI[0.85, 0.93]). No significant differences were found for pragmatic quality as a function of conformance ($F(1,127) = 0.40$, $p = .527$, partial $\eta^2 = .003$, 90% CI[0.00, 0.04]), as a function of the user group ($F(1,127) = 0.03$, $p = .868$, partial $\eta^2 < .001$, 90% CI[0.00, 0.02]), or as a function of the interaction between conformance and the user group ($F(1,127) = 1.05$, $p = .308$, partial $\eta^2 = .008$, 90% CI[0.00, 0.05]).

Hedonic quality. The hedonic quality was measured with the hedonic-quality scale of the AttrakDiff2 ($\alpha = .89$, $\omega_u = .89$, 95% CI[0.87, 0.93]). As for its pragmatic counterpart, no significant differences were found for the hedonic quality as a function of conformance ($F(1,127) = 0.85$, $p = .359$, partial $\eta^2 = .007$, 90% CI[0.00, 0.05]), the user group ($F(1,127) = 3.33$, $p = .071$, partial $\eta^2 = .026$, 90% CI[0.00, 0.09]), or the interaction between conformance and the user group ($F(1,127) = 2.09$, $p = .150$, partial $\eta^2 = .016$, 90% CI[0.00, 0.07]).

Likelihood to recommend. Participants' ratings for the likelihood that they would recommend the online shop showed no significant differences for conformance ($F(1,127) = 0.08$, $p = .772$, partial $\eta^2 = .001$, 90% CI[0.00, 0.02]), the user group ($F(1,127) = 3.25$, $p = .074$, partial $\eta^2 = .025$, 90% CI[0.00, 0.09]), or the interaction between conformance and the user group ($F(1,127) = 0.81$, $p = .369$, partial $\eta^2 = .006$, 90% CI[0.00, 0.05]).

4.3. Qualitative measures

In the analysis of the open-ended answers, a total number of 426 codes were assigned. Solely related to the study materials itself were 82 codes, which were subsequently removed from the dataset. A total number of 344 (N positive = 160, 46.5%; N negative = 184, 53.5%) codes were included in the main analysis. They were related to web accessibility (N = 36, 10.5%), usability (227, 66%), user experience (56, 16%), or coded as not assignable (25, 7.5%). The results of the analysis are presented in Table 6.

Due to the small number of codes in some categories, only the total numbers of positive and negative codes were statistically analysed. Significantly more positive experiences (χ^2 (1, N = 105) = 10.37, $p < .01$) were reported by participants with visual impairments in the AA condition compared to the NA condition, whereas no significant difference was found in negative experiences (χ^2 (1, N = 81) = 2.78, p = .096). Participants without visual impairments reported significantly fewer positive experiences (χ^2 (1, N = 55) = 6.56, $p < .05$), but also significantly fewer negative experiences (χ^2 (1, N = 103) = 7.08, $p < .01$) for the AA condition compared to the NA condition.

5. Discussion

5.1. Effects of compliance

Our motivation for the present study was to deepen our understanding of the relationship between compliance with web accessibility standards and measures related to usability and user experience. The experimental setup allowed us to manipulate the conformance of an online shop to a compliant and non-compliant level. Participants with and without visual impairments took part in the study. For the measures related to usability, we found no statistically significant differences between the compliant and non-compliant versions for both user groups. This was the case for the performance measures (task completion rate, task completion time), the outcomes related to usability (perceived task success, task satisfaction, perceived usability, pragmatic quality), and the measures related to user experience (visual aesthetic, hedonic quality). Small effect sizes were found for all the outcomes as a function of conformance to web accessibility standards (range between a partial η^2 of 0.001 for task completion rate up to 0.016 for task completion time). However, the analysis of the open-ended answers showed significantly more positive experiences for participants with visual impairments, which is as expected especially apparent for experiences related to web accessibility. In contrast, participants without visual impairments reported significantly fewer positive experiences but also significantly fewer negative experiences in the compliant condition than in the non-compliant condition, as well as overall. Given that negative user experiences have a stronger impact on the overall experience (Vaish et al., 2008), we consider this a benefit of the version that was compliant with web accessibility standards.

The present findings reveal a complex relationship between compliance with web accessibility standards and outcomes related to usability and user experience. They contrast with the positive effects found in the series of studies by Schmutz et al. (2016, 2017b,a) as well as in the studies by Pascual et al. (2014b,a, 2015), where compliance with standards significantly increased all the comparable measures. Further, although a similar experimental setup was used, substantially smaller effect sizes were observed in the present study (e.g., compared to Schmutz et al., 2017a; partial η^2 for perceived usability of 0.004 vs 0.08; partial η^2 for the visual aesthetic of 0.014 vs 0.07). These differences potentially arise from the users that participated in the study and the type of website they interacted with. Both factors indicate that the present findings demand a more differentiated perspective on conformance-based approaches to web accessibility.

Whereas the previous series of studies conducted in a laboratory or moderated remote setting, participation in the present study was fully online and unmoderated. This meant that solid skills in using the web and assistive technologies were required to participate in the first place. This is also reflected in the high self-rated experience with computers in general and with websites in particular. Since users with assistive technologies show a steep learning curve and often establish elaborate tactics to overcome web accessibility issues (Bigham et al., 2017; Moreno et al., 2020; Vigo and Harper, 2014, 2013), compliance with standards may have had less importance in the present setting. Previous studies have discussed whether participants with and without visual impairments encounter similar problems but perceive them differently in their severity (Petrie and Kheir, 2007). A comparable pattern could exist between more and less experienced users. Another main difference between the present study and past studies were the materials used. An online shop with common, highly standardised interaction patterns may have made it easier for the participants to circumvent web accessibility hurdles than in studies with less familiar materials. For example, to complete a purchase on an online shop, most users will look for some kind of checkout button, usually identified by a shopping cart. This pattern is so common that such a button is probably even found when a label or an alternative text is not optimally implemented. This illustrates that the actual impact of a barrier can be

Table 6
Number of codes per category assigned to the open-ended answers.

	Impaired eyesight		Unimpaired eyesight		Total	
	Level NA N = 84 (%)	Level AA N = 102 (%)	Level NA N = 102 (%)	Level AA N = 56 (%)	Level NA N = 186 (%)	Level AA N = 158 (%)
Positive	36 (34)	69 (66)	37 (67)	18 (33)	73 (46)	87 (54)
Web accessibility	2 (14)	12 (86)	2 (67)	1 (33)	4 (24)	13 (76)
Usability	15 (35)	28 (65)	23 (64)	13 (36)	38 (48)	41 (52)
User experience	10 (32)	21 (68)	6 (75)	2 (25)	16 (41)	23 (59)
Not assignable	9 (53)	8 (47)	6 (75)	2 (25)	15 (60)	10 (40)
Negative	48 (59)	33 (41)	65 (63)	38 (37)	113 (61)	71 (39)
Web accessibility	7 (54)	6 (46)	6 (100)	–	13 (68)	6 (32)
Usability	36 (61)	23 (39)	54 (61)	35 (39)	90 (61)	58 (39)
User experience	5 (56)	4 (44)	5 (62)	3 (38)	10 (59)	7 (41)
Not assignable	–	–	–	–	–	–

hard to determine and its perceived severity depends on the specific context (Abou-Zahra, 2008).

These considerations are in line with previous discussions that conformance to standards should be seen as a first step in web accessibility (Power et al., 2012). The observed variation of the effect sizes between the studies indicates that the impact of compliance may vary from product to product. Since every digital technology has its own distinct users and context, what is covered by standards and the perceived severity of barriers can also differ (Aizpurua et al., 2015). A significant effect of compliance with web accessibility standards alone on outcomes related to usability and user experience outcomes should therefore not be expected in every case. But this does not mean that conformance to standards is useless and not worth the effort. This is reflected in the open-ended answers of the present study, in which users with visual impairments reported more positive experiences and users without visual impairments reported fewer negative experiences in the compliant condition. Efforts to achieve compliance with web accessibility standards are a good starting point and an important milestone for accessible information and services (Power et al., 2018). To truly support inclusion, it is essential to go further and to complement conformance-based approaches with other methodologies.

5.2. Complementing compliance

The present findings highlight that inclusive experiences can only be designed with a thorough understanding of the user needs in a specific context. They also show that the checklist-based approach, as it is applied in WCAG 2.0, is reaching its limits. This can be observed in the open-ended comments from participants with visual impairments, where only a fraction of the experiences (N = 36, 10.5%) were classified as related to web accessibility. It is therefore debatable whether the participants encountered problems regarding web accessibility that are not sufficiently addressed in the given standards or whether the problems are tied to a specific context and go beyond what should be part of common guidelines. A set of standard criteria can ensure that a product is in line with important web accessibility requirements, but it cannot account for users' actual experiences in a given context (Horton et al., 2015).

Although the extension of conformance-based methodologies is not a new demand, only few tools and techniques have been established for capturing and understanding the digital experiences of users with disabilities (Power et al., 2018). The present results highlight the need for a discussion of approaches that may improve the outcomes related to usability and user experience for all user groups. Two propositions are the use of frameworks or principles and the application of user-centred or participatory design methodologies. In contrast to common web accessibility checklists, inclusive design frameworks or principles have a broader scope and try to guide the design process rather than pointing out technical implementations. Two examples for such frameworks are the Inclusive Design Principles (Swan et al., 2017) and the Accessible User Experience Principles (Horton and Quesenbery, 2014). The former proposes seven broad conventions (e.g., consider situation, be consistent, give control), and the latter proposes nine (e.g., people first, clear purpose, solid structure). Another approach is to build inclusive experiences based on established methodologies from the related field of usability and user experience: user-centred design and participatory design methods offer opportunities for better engaging users with disabilities (Henry, 2007). Whereas traditional user-centred design methods involve users but leave design decisions to professionals (e.g., contextual enquiries, user interviews, usability testings), participatory design invites users to actively define and shape the design of a product (Oswal, 2019). Standards, principles, and user involvement should complement each other to acquire a thorough understanding of users' perspectives and to facilitate the design of inclusive experiences (e.g., Brewster et al., 2019; Vollenwyder et al., 2020a).

The discussed results support current industry efforts to establish a more comprehensive view on web accessibility. For example, an early draft of WCAG 3.0 contains considerations such as a more differentiated scoring mechanism with a range from very poor to excellent for each criterion and the demand for holistic tests (Spellman et al., 2021). While further details are not yet available, the outline explicitly names user-centred design methods as part of such requirements. It is hard to predict how these first ideas will evolve and how they will be received in practice. In principle, the present results support the directions outlined in WCAG 3.0 as a reasonable advancement.

5.3. Limitations and future research

The present study has several limitations. First, the selection of the study materials could be improved for future studies. Creating an online shop from scratch had its benefits because it allowed high methodological rigour with very specific manipulations according to WCAG 2.0. But it is possible that participants perceived the content and manipulations as rather artificial. Using versions of an existing website, ideally from before and after it is optimised according to WCAG 2.0, would better account for the complexity of web accessibility issues and allow a higher external validity in a future study. This would also address the issue that a considerable percentage of users in all experimental conditions failed with some of the given tasks. One possible reason could be that the basic usability of the online shop used in the study was not optimal. The effect of a better compliance to web accessibility standards may have been diminished by such problems. Further, study materials from a less familiar context than online shopping should be considered. Based on the present results that compliance with standards alone does not necessarily provide improved usability and a satisfying user experience, it would also be interesting to compare the outcomes of websites that did and did not undergo an inclusive design process. User-centred methodologies, as outlined in the preceding section, could be applied in future studies to acquire insights about the most promising methods for creating inclusive experiences.

Second, as outlined in the main results, the study was conducted in a fully remote and unmoderated manner. As discussed, effects such as a self-selection bias among more experienced users or more dropouts among less experienced users cannot be ruled out. Future studies should take this into account and also include users that are less proficient with using the web. Further, it was not possible to observe the participants or for them to give immediate feedback, which makes it more challenging to capture a comprehensive picture of their experiences during the study. However, this setup allowed an equal or larger sample size compared to previous studies in the field (e.g., Schmutz et al., 2017b; Pascual et al., 2014b). Additionally, it allowed the participants to take part in their familiar surroundings and with their individual setup of assistive technologies (Miao et al., 2014). A replication of this study, for instance in a laboratory setting, would therefore imply various other limitations. A more promising option for future research could be to conduct entire studies or selected parts of them in synchronous remote sessions (Schmutz et al., 2017b) or to ask participants to record and comment on their attempts. Both approaches would allow a richer picture of experiences with digital technologies.

Finally, the present study equates web accessibility with efforts to make the web accessible to users with visual impairments and ignores users with other disabilities, a pattern which is frequently found in research and practice (Vollenwyder et al., 2020b). Although users with visual impairments are an important target group for web accessibility, it is essential to highlight that other sensory, motor, or cognitive impairments should receive equal attention. Replicating this study with another group of users with disabilities would benefit the validity of the results and provide more comprehensive insights into experiences with digital technologies. Further, the question regarding an adequate representation of various user groups leads to another research gap that future studies could address. The recommended application of user-centred design methodologies also requires good strategies for recruiting users with disabilities (Henry, 2007). In the context of web accessibility, this is a challenging task since a category such as "motor impairment" is vast and includes a multitude of disabilities that can substantially influence a user's perception of interactions with digital technologies. Best practices for approaching this complexity would therefore be helpful in research and practice.

5.4. Implications for practitioners

In practice, web professionals often face the challenge of advocating web accessibility efforts towards their stakeholders (Vollenwyder et al., 2019). The present results provide arguments in favour of taking a differentiated position in such debates. First of all, it remains vital to consider existing standards such as WCAG 2.0 while designing accessible information and services on the web. Even large projects will not be able to actively include users that represent the diversity of disabilities, assistive technologies, and levels of experience with digital technologies (Henry, 2007). Conformance to web accessibility standards can provide a solid foundation that covers the most important technical aspects. At the same time, it is also important to emphasise that significant benefits cannot be expected from compliance in every case. For example, stakeholders may be disappointed if they still receive negative user feedback for their freshly certified website. As a web professional, it is important to provide context, to explain how such feedback can be interpreted and why it does not question previous web accessibility efforts. As seen in the present study, it might be necessary to explain that a product in a highly standardised context, such as an online shop, does not stand out through compliance with standards alone.

Conformance to web accessibility standards should be seen as a first step for inclusive experiences. Additionally, we recommended advocating for a user-centred perspective during the whole design process of a product and including the user's perspective as early as possible. For example, users with disabilities and with various proficiency levels should be included in user research activities ahead of a project, design drafts should be challenged before being handed over to developers, and testings with users should be scheduled soon after the first implementation. Such measures are usually possible with limited resources, and they prevent expensive retrofitting activities in a later stage of product design (Urban and Burks, 2006). Further, the involvement of users with disabilities has proven to be an effective method for fostering awareness and knowledge about web accessibility at all organisational levels (Vollenwyder et al., 2020a).

Finally, we encourage all web professionals to share their inclusive design examples. Since there is still a lack of established tools and techniques for capturing and understanding the digital experiences of users with disabilities, such insights are valuable for developing best practices to complement conformance-based approaches. Additionally, emphasising personal responsibility in every professional role is an important motivation for considering web accessibility (Vollenwyder et al., 2019). Intensive collaboration among the community of web professionals supports this notion and provides opportunities to reach out for help during an inclusive design process.

6. Conclusion

The present work investigated how compliance with web accessibility standards shapes the experiences of users with and without disabilities. The results from a randomised controlled experiment showed that significant effects on outcomes related to usability and user experience cannot be expected for all users in every context. Since daily work on accessible information and services often relies exclusively on given standards, we recommend adopting a more differentiated perspective on what can be achieved through conformance. While standards serve as a solid foundation, we propose complementing them with user-centred and participatory design approaches. We hope our research encourages web professionals to continue their quest towards a web for everyone.

CRediT authorship contribution statement

Beat Vollenwyder: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft. **Serge Petralito:** Conceptualization, Methodology, Software. **Glena H. Iten:** Conceptualization, Methodology, Software. **Florian Brühlmann:** Conceptualization, Methodology, Formal analysis, Writing – review & editing. **Klaus Opwis:** Supervision. **Elisa D. Mekler:** Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix. Manipulations

See Table A.7.

Table A.7
Overview of the manipulated website characteristics according to WCAG 2.0.

Number	WCAG name	NA implementation	AA implementation
Perceivable			
1.1.1	Non-text Content	Text alternatives were not provided for images and icons.	Every image and icon on the website provided an appropriate text alternative
1.3.1	Info and Relationships	Content was not fully structured by heading tags. Forms did not contain label tags. Tables did not contain heading tags.	Content was fully structured by heading tags. Forms contain label tags. Tables contain heading tags.
1.3.2	Meaningful Sequence	Content sequence for the page "Information" was visually but not programmatically meaningful.	Content sequence for the page "Information" was visually and programmatically meaningful.
1.4.1	Use of Colour	Active navigation and links were indicated by a different colour.	Active navigation and links were indicated by underlined text.
1.4.3	Contrast (Minimum)	The contrast between headings and background was 2.9:1 (#989898 | #FFFFFF). The contrast between text and background was 4.1:1 (#7D7D7D | #FFFFFF). The contrast between text and buttons was 2.2:1 (#FFFFFF | #43C94D). Background images in the heading section were not adjusted for good readability.	The contrast between headings and background as well as text and background was 15.9:1 (#222222 | #FFFFFF). The contrast between text and buttons was 4.5:1 (#FFFFFF | #128A1B). Background images in the heading section were adjusted for good readability.
1.4.8	Visual Presentation	Text blocks did not have a maximum width and were justified.	Text blocks had a maximum width of 80 characters and were left aligned.
Operable			
2.1.1	Keyboard	Autocomplete was not operable with a keyboard.	Autocomplete was fully operable with a keyboard.
2.4.1	Bypass block	Skip links and access keys were not available.	Skip links and access keys were available; they were visually hidden at the top of the website.
2.4.2	Page Titled	Page titles were not adapted to the content.	Page titles were adapted to the content.
2.4.3	Focus Order	Using the tab key on product pages and in the contact form did not move one between the fields in a meaningful order.	Using the tab key moved one between all the fields received focus in a meaningful order.
2.4.5	Multiple Ways	An alternative way to the products was not provided.	Direct links in the footer section provided an alternative way to the products.
2.4.6	Headings and Labels	Some headings were shortened to be less descriptive.	Headings were descriptive for the related content.
2.4.7	Focus Visible	Keyboard focus indicator was not visible.	Keyboard focus indicator was visible and optimised for comfortable recognition.
2.4.10	Section Headings	Some section headings were removed.	Section headings were used to organise the content.
Understandable			
3.1.1	Language of Page	Default language was fixed to English.	Default language matched the current language.
3.1.4	Abbreviations	Product origins were declared with abbreviations of the countries.	Product origins were declared with full names of the countries.
3.2.3	Consistent Navigation	Not all navigation links were presented on the search and checkout page.	Navigational links appeared consistently.
3.2.4	Consistent Identification	Some buttons to add products to the cart differed in design, although they had the same functionality.	Buttons were designed consistently.
3.3.1	Error Identification	Error identification was not provided for forms.	Error identification using "required" attributes was provided for all forms.

(*continued on next page*)

Table A.7 (*continued*).

Number	WCAG name	NA implementation	AA implementation
3.3.2	Labels or Instructions	Required fields were presented in bold text without additional text alternatives.	Required fields were presented in bold text, were labelled with an asterisk, and were accompanied by an additional hidden text alternative.
Robust			
4.1.2	Name, Role, Value	Role attributes were not used.	Role attributes were used for alert messages and for the validation messages in forms.

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My Train Talks to Me: Participatory Design of a Mobile App for Travellers with Visual Impairments

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Abstract. Travellers with visual impairments may face substantial information gaps on their journeys by public transport. For instance, information displayed in trains, as well as on departure boards in train stations and on platforms, are often not available in acoustic or tactile form. Digital technologies, such as smartphones or smartwatches, can provide an alternative means of access. However, these alternatives do not guarantee that the user experience is comparable in value, quality and efficiency. The present case study details a participatory design process, where travellers with visual impairments co-designed a mobile app. The goal was to tackle information gaps on journeys by public transport and to learn how participatory design can facilitate the provision of comparable experiences for users with disabilities. Travellers with visual impairments were involved in a collaborative process in all project phases, including problem identification, technical feasibility, proof of concept, design and development. Participatory design contributed to a thorough understanding of the user perspective and allowed the app to be optimised for the needs of travellers with visual impairments. Furthermore, co-design proved to be an effective method for fostering awareness and knowledge about digital accessibility at all organisational levels.

Keywords: User experience · Digital accessibility · Participatory design · People with visual impairments · Case study

1 Introduction

Beginning a journey, visiting your loved ones, or commuting daily to work: There are many reasons for boarding a train. People with visual impairments also share this daily travel routine. However, this group of travellers may face additional challenges on their journeys by public transport. In Switzerland, where the present case study was conducted, no immediate acoustic or tactile information

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is available to aid people when they board trains. Announcements in trains are usually made only a few minutes before departure, which can lead to stressful situations or even trips to the wrong destination. A similar dearth of information exists in train stations and on platforms. Currently, travellers with visual impairments have no direct means of accessing the information on departure boards listing the next available train connections. There are alternative means for obtaining this information; for instance, by querying the timetable provided in the mobile app of the Swiss Federal Railways. Nonetheless, such alternatives require extra effort, and the experience is hardly comparable to a quick glance at a departure board. As a consequence, this information gap may substantially limit a traveller's autonomy and comfort.

Information systems installed in trains, train stations and on platforms have long life cycles, making it more difficult to address information gaps that were not previously considered. Digital technologies, such as smartphones or smartwatches, can provide an alternative means of access. Although these personal devices are widely available and have become pervasive in everyday life, they still do not guarantee a comparable experience [1]. Comparable experience here refers to digital information and services that are comparable in value, quality and efficiency for each user [9]. For instance, the ease of the aforementioned quick glance at the departure board could be replicated for travellers with disabilities by equipping apps with device features such as geolocation and screen reader support, thereby providing an efficient alternative means for them to interact with local information. Thus, designing comparable experiences for as many people as possible requires more than the mere transfer of identical content and functionalities to other technologies.

1.1 Access to Experience

Power, Cairns and Barlet [7] describe three layers involved in achieving comparable experiences for users with disabilities. The authors refer to the work on digital accessibility that focuses on providing basic access to technologies as *First Wave Inclusion*. Basic access can be provided by offering alternative input modes (e.g., switch access that replaces interactions via touchscreen for users with limited dexterity in their hands) and by translating information into alternative output modalities (e.g., access by screen reader for users with visual impairments). While work on basic access remains vital for digital accessibility, recent work has broadened the perspective and moved away from the focus on mainly technical aspects [5,8].

Second Wave Inclusion shifts the perspective towards enabling users with disabilities to achieve their goals [7]. This leads to a more usability-oriented understanding of digital accessibility, including traditional criteria such as effectiveness, efficiency and satisfaction in a specified context of use [5]. The opinion that digital accessibility and usability are related concepts is regularly discussed in research [6] and is widely accepted by accessibility experts [12]. Further, the understanding that this relationship benefits the overall quality of a product was shown to be a main motivation for considering digital accessibility [10].

Based on the analyses of access and enablement covered in the two previous layers, *Third Wave Inclusion* focuses on understanding the subjective experiences of users with disabilities in an interactive system [7]. This perspective goes beyond performance-related criteria and includes aspects related to user experience such as affect, trust or aesthetics [1]. However, in the digital accessibility field, this more holistic perspective is rarely adopted [4], and only a few tools and techniques have been developed to capture the subjective experience of users with disabilities [7]. A frequently cited approach is *participatory design*, in which users with disabilities actively define and shape the design of a product [4]. Participatory design contrasts with traditional user-centred design methods that involve users but leave their design decisions to be made by a project team of specialised professionals.

In the present case study, we detail the development of a mobile app, which was co-designed by travellers with visual impairments. The project was conducted in collaboration with the Swiss Federal Railways and pursued the goal of identifying and closing crucial information gaps that hinder travellers with disabilities during their journeys by public transport. Rather than giving specific advice on how to implement an accessible app, this report aims at providing insights into a participatory design process and also inspiring similar activities in other projects.

2 Case Study

2.1 Problem Identification

In a first phase, we asked travellers with disabilities to provide us with their experiences regarding any information gaps that they confronted during journeys by public transport. For this purpose, we contacted the Advisory Board for Barrier-free Travel of the Swiss Federal Railways, which represents travellers with visual, hearing and motor impairments. The board consisted of one person with a central scotoma since childhood (m, 45), two people who have been almost blind since childhood (f, 42; m, 59), one person with severe hearing loss since early childhood (f, 51), one person with age-related hearing loss (m, 77), one person with cerebral palsy since birth (m, 42), a low vision optician (m, 62), an acoustician (m, 80) and an expert in the field of barrier-free public transport (m, 71).

In two workshops, we mapped a complete user journey, ranging from planning, arriving at the station, finding the platform, boarding the train, travelling to the destination, and orienting oneself after arrival. For each part of the user journey, the representatives of the advisory board introduced potential information gaps and rated these according to their severity. Later, these insights were enriched with observations from first-hand experiences on an exemplary journey. For instance, the representatives with visual impairments demonstrated their lack of information when boarding a train by giving the non-disabled project members simulation glasses so that they could experience this issue personally.

2.2 Technical Feasibility

Detailed problem descriptions derived from the user journeys were used as input for a *hackathon*. In a hackathon, teams of programmers and other specialists involved in software development collaborate intensively on a given project over a few days. One of the teams, including a blind programmer (m, 44), focused on information availability when boarding a train. With the development of an app using Bluetooth beacons and publicly available information from the Swiss public transport's open-data platform[1], the team was able to prove the app's technical feasibility and its compatibility with assistive technologies. A few weeks later, another team extended the prototype in a second hackathon with regard to information availability in train stations and on platforms. By using geofencing based on GPS positioning, it was possible to provide a digital version of the departure boards which showed the next available train connections at the current position.

2.3 Proof of Concept

We decided to further develop the ideas created in the technical feasibility phase for multiple reasons. First, the two aforementioned issues belonged to the most pressing information gaps for travellers with visual impairments. Second, the proposed solutions showed potential for being extended to travellers with other forms of disability; for example, by providing acoustic announcements in text form for people with hearing impairments. Third, another project involved installing Bluetooth beacons on a selection of train lines to test a different application, which allowed us to start our project immediately using existing infrastructure. A basic test app applying components built in the technical feasibility phase was distributed to a group of 34 interested travellers with visual impairments. The participants regularly travelled on specific train lines that were already equipped with Bluetooth beacons. They provided feedback via their communication channel of choice (e.g., via email, phone or voice messages). In addition, we conducted three exemplary journeys with a total of 10 travellers (6 women, 4 men; 5 blind, 5 with severe visual impairments) to discuss the app's functionalities and design in a real context. During the proof of concept phase, we collaboratively created first drafts for the final product design. For instance, the test app featured the concept of the master-detail pattern, providing a short overview of the travel information with an option to see more content. Participants deemed this concept as impractical in the present context, since it requires browsing through an often changing list and an additional click to look for further information. In collaboration with the participants, a concept using tab navigation at the bottom end of the app and reserved areas for the most important information was outlined. These reserved areas have a fixed position on the screen and enable quick access and orientation using a screen reader.

To decide whether to continue the project, the proof of concept phase was closed with a questionnaire answered by a total of 14 participants (age $M = 55.3$,

[1] https://opentransportdata.swiss/en.

$SD = 10.3$, range 30–71; 4 women, 10 men; 7 blind, 4 with severe visual impairments, 3 with light visual impairments). Participants used the test app with various combinations of assistive technologies, including screen reader and voice control ($N = 6$), screen reader, voice control and inverted colours (3), screen reader only (3), and screen magnification (1). They rated the overall impression of the test app positive ($M = 4.23$; $SD = 1.1$; 1 = *worst rating*, 5 = *best rating*). To gain further support for the project, we decided to use the test app to spread awareness of digital accessibility issues within the organisation. In 3 workshops, a total of 60 employees of the Swiss Federal Railways were invited to personally experience the addressed information gaps. Travellers with visual impairments were present during these workshops and shared their experiences in dealing with these issues.

2.4 Design

Based on the insights generated in the previous phases, we compiled a final conceptual design. The app was named SBB Inclusive (i.e., SBB stands for Schweizer Bundesbahnen, Swiss Federal Railways). Next, we asked four blind users (age $M = 46.7$, $SD = 14.4$, range 30–65; 1 woman, 3 men) to participate in a usability test, in which they solved typical tasks with an early prototype [3]. Often, such tests are carried out with pen and paper or wireframes, which cannot be accessed directly by users with visual impairments. A simple web prototype built using HTML and CSS proved to be an effective workaround. This allowed us to test the navigation structure, the order of the displayed elements, and the richness of information directly using a screen reader. Participants had the choice between using either a test device or their own personal device. This allowed them to participate in the test while using their own familiar settings, such as their personal screen reader speech rate. To refine the concept, we discussed findings with the participants immediately after each test session and collaboratively outlined design improvements.

Finally, we created a visual design for the app, taking the accessibility features of the operating systems into account. For instance, a specific screen layout was designed for large text settings, which allows for text resizing without loss of content or functionality. The evolution of the app during the design phase is presented in Fig. 1.

2.5 Development

An app version for iOS using SwiftUI and a version for Android using Flutter were created from scratch. We deemed both technologies as being optimally suited for building the intended features. Travellers with visual impairments who participated in the proof of concept phase were invited to upgrade their apps to the new app and were asked to give their feedback on the ongoing development using a built-in contact form. At the date of this publication, the new app was just made available for testing. Therefore, little feedback has been received so far: however, most of it expresses a positive first impression of the final version of the app. The public release of SBB Inclusive is planned for fall 2020.

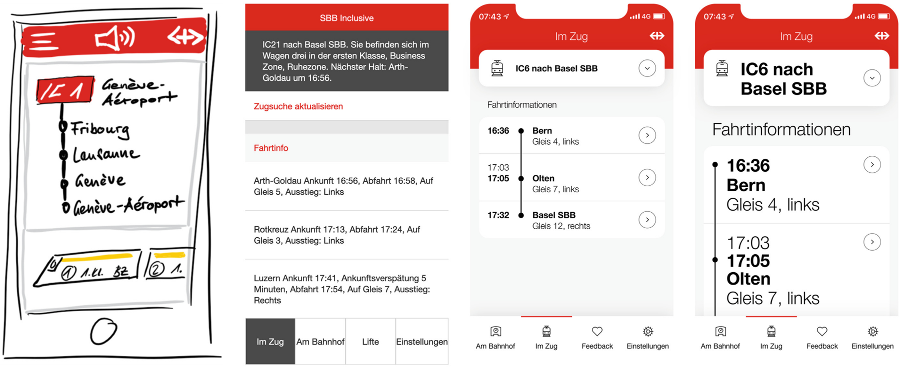

Fig. 1. Evolution of the app during the design phase. From left to right: first scribbles, HTML prototype, final design and final design with increased text size.

2.6 Future Development

With regard to future development, we plan to focus on additional information gaps that were revealed in the problem identification phase. Current ideas include developing features to display acoustic announcements in text form to travellers with hearing impairments, to monitor the status of elevators in train stations for travellers with physical impairments, and to provide information in reduced language complexity for travellers with cognitive and learning disabilities.

3 Discussion

Travellers with visual impairments participated in all phases of the present case study. The co-design process allowed us to obtain a thorough understanding of information gaps during journeys by public transport from a user's perspective. Especially, the workshops with representatives from the advisory board in the problem identification phase and the exemplary journeys in the proof of concept phase proved to be helpful for this purpose. These occasions also created a space for collaboratively drafting ideas, which led to the conceptual design used in the final product. In the present case study, participatory design allowed us to attain a level of quality which would arguably not have been achieved with traditional user-centred design methods.

Further, the shared understanding provided a solid basis for the development phase of the app, which required continuous design decisions that had to be in line with user needs. For this mainly technical phase, it would have been a major advantage to have a person with visual impairment as a fixed member of the development team [4]. This was partly the case during the technical feasibility phase and proved vitally important for the iterative testing of solutions, for integrating resources from first-hand experiences into the product, and for receiving hints on how similar functionalities are solved in other apps. Future projects should extend participation to all project phases and staff a more diverse development team. At the same time, close involvement of a broad user group should be maintained. Such a setup allows for a balance between the expertise of a project team and the perspectives of unbiased users.

Another insight from the present case study was the importance of the impact that participatory design has on stakeholders within the organisation. Recommendations to involve users with disabilities in the development process in order to foster awareness at all organisational levels were put into practice effectively [10]. In particular, the proof of concept phase with its workshops which allowed participants to personally experience the inconvenience caused by the information gaps proved to be an effective tool for promoting knowledge about digital accessibility within the organisation. Internal stakeholders who were initially somewhat indifferent to information gaps for travellers with disabilities soon saw the importance of these issues while collaborating with travellers with visual impairments. The involvement also contributed to a reduction in misconceptions regarding digital accessibility; for instance, the prevalent belief among stakeholders that aesthetics and technologically advanced products would be compromised by introducing accessible solutions [2]. An extension of the participatory design process to other groups of users with disabilities would benefit this promotional effect. Since the scope of digital accessibility often centres around users with visual impairments [11], such a step could broaden an organisation's awareness for various perspectives and motivate it to invest in providing comparable experiences for all user groups. Another benefit of involving internal stakeholders closely was the opportunity to exploit synergies with other projects. The possibility to reuse an existing technical infrastructure was crucial to obtaining the technical solution described in the present case study, as this allowed the project to start immediately and shortened the implementation time substantially. Perhaps, there will be further synergies in other contexts that can be used in a creative way to support digital accessibility.

4 Conclusion

In the present case study, a mobile app was co-designed by travellers with visual impairments to create a user experience that is comparable in value, quality and efficiency to that of non-disabled travellers. Participatory design contributed to a thorough understanding of the user perspective and allowed us to optimise the app to the needs of travellers with visual impairments. By extending the use of participatory design to all development phases and by staffing projects with a more diverse team, these observed benefits could be further employed in future projects. Interactions between travellers with visual impairments and the stakeholders within the organisation helped to spread accessibility awareness and knowledge at all organisational levels and triggered synergies with other projects. Future work should broaden the spectrum of disabilities considered to include as many people in as many situations as possible. We hope that our research will encourage project teams to benefit from a wide range of user perspectives in order to improve their work.

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