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Towards Design Theory for Accessible IT Artefacts

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Tiivistelmä

Informaatioteknologia-artefaktien (IT-artefaktien), kuten verkkosivustojen, sovellusten ja käyttöliittymien saavutettavuus tarkoittaa sitä, että ihmiset erilaisine ominaisuuksineen ja kykyineen voivat käyttää niitä. Vaikka saavutettavuus on ihmisoikeus, IT-artefaktit eivät kuitenkaan ole aina saavutettavia. Käytettävissä olevista saavutettavuusohjeista huolimatta tarvitsemme suunnitteluteorioita, jotka ohjaavat IT-artefaktien suunnittelua, jotta niistä tulisi saavutettavia kaikille IT-artefaktin käyttäjille.

Tämä väitöskirja on yhteenveto neljästä artikkelista, jotka käsittelevät tätä ongelmaa. Tutkimukset ovat tehty laadullisilla menetelmillä, joihin on sisältynyt narratiivinen kirjallisuuskatsaus, systemaattinen kirjallisuuskatsaus sekä suunnittelutieteellinen menetelmä sisältäen osallistavan suunnittelun ja haastattelut. Ensimmäisessä artikkelissa kehitetään kuvaileva saavutettavuuden teoria, jolla saadaan käsitys saavutettavuuden rakenteesta ja joka näyttää mahdolliset muuttujat ihmisen kyvyissä, tehtävissä ja konteksteissa, sekä niiden väliset suhteet. Toinen artikkeli kuvaa saavutettavuuteen vaikuttavia tekijöitä johtamisen, kehityksen, käyttäjän ja IT-artefaktin ominaisuuksien näkökulmista, mukaan lukien roolit ja toimenpiteet, joita näillä kohteilla on. Kaksi muuta artikkelia kehittävät ohjeistuksen sisällöntuottajien työn tueksi saavutettavan verkkotekstin tuottamiseksi.

Väitöskirjassa esitetään kolme ratkaisevaa tekijää saavutettavuuden tietämyksessä: (1) olettamukset käyttäjien kyvyistä (2) käyttäjien todelliset tarpeet ja (3) tekijät kehitysketjussa. Näiden tekijöiden tuntemus auttaa erityisesti suunnittelutieteilijöitä muodostamaan ohjaavaa tietoa ammattilaisille saavutettavien IT-artefaktien saavuttamiseksi. Täten tutkijat voivat paremmin tunnistaa muuttujat, niiden väliset suhteet ja saavutettavuuteen vaikuttavat tekijät, jotka liittyvät käyttäjän kykyihin, johtamiseen, kehittämiseen, sisällöntuottamiseen, tehtäviin ja kontekstiin, kun IT-artefaktia suunnitellaan tiettyä tehtävää ja käyttökontekstia varten.

Asiasanat: Saavutettavuus, Saavutettavuusteoria, IT-artefaktit, Tietojärjestelmätiede, Suunnittelutiede, Suunnitteluteoria, Ihmisen ja tietokoneen välinen vuorovaikutus

Abstract

Accessibility in the use of information technology (IT) artefacts, such as websites, applications, and user interfaces, means that they are designed in such a way that people with the broadest range of abilities can use them. However, although accessibility is a human right, IT artefacts often remain inaccessible. Aside from the available accessibility guidelines, we need sufficient design theories that explicitly state how accessibility should be addressed and designed to develop accessible IT artefacts for all users.

This dissertation summarises four articles that address this problem. These studies are conducted with qualitative approaches that include a narrative literature review, a systematic literature review and a design science method comprising a participatory design and interviews. The first article develops an explaining theory of accessibility to gain an understanding of the construct of accessibility, showing possible variables of human abilities, tasks and contexts and their relationships in IT use. The second article illustrates the factors in management, development, user, and IT artefact features, including the roles and actions that these domains have and how they affect the realisation of accessibility. The other two articles contribute to accessibility guidance to improve and support content creators' text production and writing process of accessible online text in the web context.

The dissertation underscores three key determinants of the knowledge of accessibility: (1) assumptions of users' abilities; (2) users' actual needs; and (3) factors in the development chain. The foregoing factors contribute to the knowledge of accessibility and would help researchers, particularly design scientists, form prescriptive knowledge for practitioners to achieve accessible IT artefacts. Thus, researchers could better identify the variables, relationships and affecting factors in human abilities, management, development, content creation, tasks, and contexts that need to be addressed when designing IT artefacts for certain tasks and use contexts.

Keywords: Accessibility, Accessibility Theory, IT Artefacts, Information Systems, Design Science, Design Theory, Human-Computer Interaction

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Vaasa, November 2022

Juho-Pekka Mäkipää

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Abbreviations

AM	Accessibility Model
AT	Assistive Technology
HCI	Human-Computer Interaction
IT	Information Technology
IS	Information Systems
WCAG	Web Content Accessibility Guidelines

Vocabulary

Prescriptive Knowledge:	‘A special case of prediction exists where the theory provides a description of the method or structure or both for the construction of an artifact (akin to a recipe). The provision of the recipe implies that the recipe, if acted upon, will cause an artifact of a certain type to come into being’ (Gregor, 2006: 619).
Design Theory:	‘A design theory is a prescriptive theory which explicitly says how to design and develop an artifact and how a process can be carried out in a way which is both effective and feasible.’ (Walls et al., 1992: 37).
IS Design Theory:	‘…an IS design theory shows the principles inherent in the design of an IS artifact…’ (Gregor & Jones, 2007: 322).
Artefact:	‘The term *artifact* is used to describe something that is artificial, or constructed by humans, as opposed to something that occurs naturally’ (Gregor & Jones, 2007: 313).
IS Artefact:	‘…accomplishes some end, based on knowledge of both IT and human behaviour.’ (Gregor & Jones, 2007: 322).
IT Artefact:	IT artefact is defined as an application (e.g. web application, web site, user interface…) of an IT that enables or supports a specified task embedded within a structure in a specified context (Alter, 2008).

Original Articles

This dissertation contains an overview of the following articles, which are referred to by Roman numerals.

I. Mäkipää, J.-P. (2022). Explaining Accessibility: Possible Variables in Users' Abilities, Tasks and Contexts in IT Artefact Use. *Unpublished.*

II. Mäkipää, J.-P., Norrgård, J., & Vartiainen, T. (2022). Factors Affecting Accessibility of IT Artifacts: A Systematic Review. *Communications of the Association for Information Systems.* (forthcoming), In Press.

III. Mäkipää, J.-P., & Isohella, S. (2022). Designing Heuristics for Accessible Online Text Production. *Scandinavian Journal of Information Systems*, 34(1), 165–198. https://aisel.aisnet.org/sjis/vol34/iss1/5

IV. Mäkipää, J.-P., & Isohella, S. (2022). Implementation of Online Text Accessibility Heuristics. *Unpublished.*

Article I: As the solo author, I designed the study, collected and analysed the data, and wrote the paper.

Article II: As the first author, I designed the study, led the research process, and collected and analysed the data with my co-authors. My co-authors contributed by editing the paper in general.

Article III: As the first author, I led the research process and conducted the literature review. Together with my co-author, I designed the study, analysed the data and wrote the paper.

Article IV: As the first author, I led the research process and designed the study. My co-author and I jointly wrote the paper.

1 INTRODUCTION

1.1 Motivation

We humans are vastly different as users of information technology (IT). The tasks that we perform and our contexts of use vary. Moreover, as human beings, we differ in our abilities. The World Health Organization (WHO) perceives human disability as a socially created problem in which an unaccommodating digital environment is created by neglecting the rights of persons with disabilities (WHO, 2002). Therefore, the systems and technologies that we design should be as inclusive and as accessible as possible, so people would not be disenfranchised or oppressed (Association for Computing Machinery, 2021; Association for Information Systems, 2021; Hanson, 2017). Many previous studies and existing laws define accessibility by referring to the International Organization for Standardization (ISO) Standard 9241–11:2018, which defines accessibility as the

> 'extent to which products, systems, services, environments, and facilities can be used by people from a population with the widest range of user needs, characteristics, and capabilities to achieve identified goals in identified contexts of use'. (ISO, 2018)

The concept of accessibility in relation to people is universal in nature. Concepts that tend to cover all diversities in users' abilities in various contexts are encompassed by the term 'universal accessibility' (Obrenovic et al., 2007; Savidis & Stephanidis, 2004). In this dissertation, the term 'user' refers to a person who interacts with the product using his/her natural senses. IT artefact refers to an IT application (e.g. web application, website, user interface...) designed to enable or support a specified task embedded within a structure in a specified context (Alter, 2008). Despite the large body of Information Systems (IS) and Human–Computer Interaction (HCI) research related to human behaviour, IT artefacts often remain inaccessible (Brajnik et al., 2011; Martins et al., 2017; Santana & Baranauskas, 2015; Vollenwyder et al., 2019). However, the IS and HCI literature comprise a multitude of studies on accessibility investigating how to design IT artefacts for the use of people with certain disabilities. For example, the majority of accessibility-related studies are focused on catering to the needs of blind and low-vision people (Mack et al., 2021; Paiva et al., 2021). Moreover, the literature presents techniques and methods that can be applied for capturing a specific user population's needs successfully (c.f. Link et al., 2006; Paiva et al., 2021).

In practice, the provision of accessible digital services is enshrined in many legislations. For example, in Europe, a European Union (EU) directive (EU Directive 2016/2102) on the accessibility of websites and mobile applications of public sector bodies requires public services to develop online platforms, including websites and mobile applications, for enhanced accessibility (Directive 2016/2102 (2016) of the European Parliament and of the Council of 26 October 2016, 2016; European Telecommunications Standards Institute, 2015). Governments and public organisations aim to provide digital services and share information on websites in such forms that all citizens are able to use. To promote accessibility, organisations such as the World Wide Web Consortium (W3C) have drawn up guidelines used by the law in their determinations. One of the major Web Content Accessibility Guidelines (WCAG) is considered *de facto* in practice and in research (Aizpurua et al., 2015; Martins et al., 2017; Vollenwyder et al., 2019). However, these guidelines are not adequate to create accessibility for all populations. For example, WCAG covers around half of the accessibility problems that blind users encounter on the web (Petrie et al., 2003; Vigo & Harper, 2013). Furthermore, these guidelines are geared towards web practitioners, webmasters and web developers, which makes their application difficult in content production (Minin et al., 2015; Vollenwyder et al., 2019). Therefore, it is evident that content creators do not have appropriate guidelines, particularly for producing accessible text content, which remains as the main form of content on the web (Kalender et al., 2018; Rello et al., 2016).

Overall, despite this very advanced progress, science and practice still lack a concrete theory of how to design IT artefacts that integrate the needs of different abilities of users into a single solution (Meiselwitz et al., 2010). Addressing the abilities of many different users through a single solution requires that we first identify what the ability to use IT artefact means. That is, we must understand how accessibility is scoped and what human-related processes are associated with it. For example, previous studies have argued about the scope of accessibility and usability, leading to various problems (Aizpurua et al., 2016; Petrie & Kheir, 2007; Santana & Baranauskas, 2015; Sauer et al., 2020; Yesilada et al., 2015). For one, large amounts of definitions and perspectives make web accessibility difficult for members of the research community to interact or share their understanding and knowledge (Yesilada et al., 2015). Furthermore, the ambiguous scope may result in a deterioration in the accuracy of the development and evaluation of both features (Aizpurua et al., 2016). This also means that in practice, IT artefacts can become accessible, but their usability remains weak, or their usability may be good, but their accessibility remains weak (Aizpurua et al., 2016). Thus, the scope of accessibility and the affecting factors around the concept should be identified to create accessible IT artefacts (Santana & Baranauskas, 2015).

However, design theories that explicitly state how to design and develop artefacts (Gregor & Jones, 2007; Walls et al., 1992) that cover the broadest range of user needs are less available. The problem is that traditionally, in design science research, scientists collate information about the different user abilities and characteristics from the environment of the target (observed behaviour) (Hevner et al., 2004). However, when an artefact is designed for the use of anyone, it is difficult or nearly impossible for researchers to obtain information and requirements from people all around the world. Therefore, researchers need to use a knowledge base (prior research) to cover the possible needs of users who are not included in the study. However, descriptive knowledge of the potential needs of users (human abilities) that indicates what is associated with the phenomenon and its environment (Gregor & Hevner, 2013), as well as the guiding theories to cover these needs, is fragmented. Particularly prescriptive design theories that pay attention to the 'people aspect' (Gregor et al., 2020), such as user capability to use IT artefacts (i.e. construct of 'accessibility'), which is built on explanatory and predictive knowledge (Gregor, 2006; Gregor et al., 2020, p. 202) to establish what this concept consists of and how the theory beyond the pursued extent is described, are less available. That is, design theories with theoretical underpinnings (Walls et al., 1992) lack the foundational theory of accessibility. With a theory that explains the different user abilities and reveals the factors that influence the use of IT artefacts, researchers have better premises to create design theories that state how to design and develop IT artefacts for certain tasks and contexts and are accessible for all user populations.

This problem can be justified with the following examples: 1) IS theories, such as technology acceptance models, do not consider users' perceptions of accessibility, even if they are originally designed to provide practical contribution to user-centred design, user-oriented Management Information Systems research and HCI research (Zhang et al., 2006); 2) Studies that expand acceptance models with an accessibility relevance do not describe the construct of accessibility (Lin, 2013); 3) Accessibility approaches are mainly for the same purpose (Obrenovic et al., 2007; Persson et al., 2014); 4) Research constantly argues with the definition of accessibility and its interplay with usability (Aizpurua et al., 2016; Santana & Baranauskas, 2015); 5) Overall design principles of accessibility often aim to build alternatives for the interaction (Savidis & Stephanidis, 2004), but in practice, practitioners are not eager to create many versions of the system (Lazar et al., 2004), which are actually in contrast to the principles of inclusion.

1.2 Objectives

The aim of this dissertation is to complement the body of knowledge so that researchers, particularly design scientists, have better premises to form design theories for practitioners to achieve accessible IT artefacts for certain tasks and contexts. This aims to improve rigorousness in the use of a knowledge base for design artefact development in design science research.

Therefore, I ask: **What are the key determinants of knowledge to form design theories for achieving accessible IT artefacts?**

The research problem and its importance in this dissertation can be justified as follows: complex descriptions of the constructs of accessibility in IS and HCI research are limited, leading to difficulties in communicating the scope of accessibility, its interconnections with usability and user acceptance, and its universal aspect (Aizpurua et al., 2016; Petrie & Kheir, 2007; Santana & Baranauskas, 2015; Sauer et al., 2020; Yesilada et al., 2015). The factors that affect accessibility for a specified group or population (e.g. people with low vision) are well known, but factors in the overall picture that include the widest range of abilities of the target population, factors relating to IT development, and factors relating to managing the development of accessibility are fragmented (Lazar et al., 2004; Leuthold et al., 2008; Vollenwyder et al., 2019). Then, as is known, the development of accessibility needs to include a number of stakeholders so the outcome can become accessible, but the key guidelines are directed to developers, which makes their application difficult for content creators who play a crucial role in the creation of accessible content for IT artefacts (Minin et al., 2015; Vollenwyder et al., 2019).

1.3 Research Framework

As a research framework for this dissertation, I juxtaposed the studies in Articles I–IV to the model of design science research by Hevner (2007) and Hevner et al. (2004). Hevner's model is a conceptual framework that combines behavioural science and design science paradigms for understanding, executing and evaluating design science research in the IS discipline. According to this model, the nature of design science research consists of three cycles: the relevance cycle with the environment, the rigor cycle with the knowledge base, and the design cycle with the artefact design processes and evaluation. In this model, the environment involves people, organisations, and technology, which are aspects of the IS context and a potential problem source. People's activities involve their roles, abilities and characteristics in the organisation. The organisation consists of strategies, structures, culture and processes. Technology, including infrastructure, applications, communication and development, enables people to perform processes in an organisation (vom Brocke & Rosemann, 2015).

In design science study, scientists collect requirements from these domains in continuous relevance cycles to gain insights into the problem solution. Simultaneously, scientists utilise past knowledge base using foundations of theories, frameworks, models, methodologies, and others, which they utilise in constructing an artefact (see Figure 1).

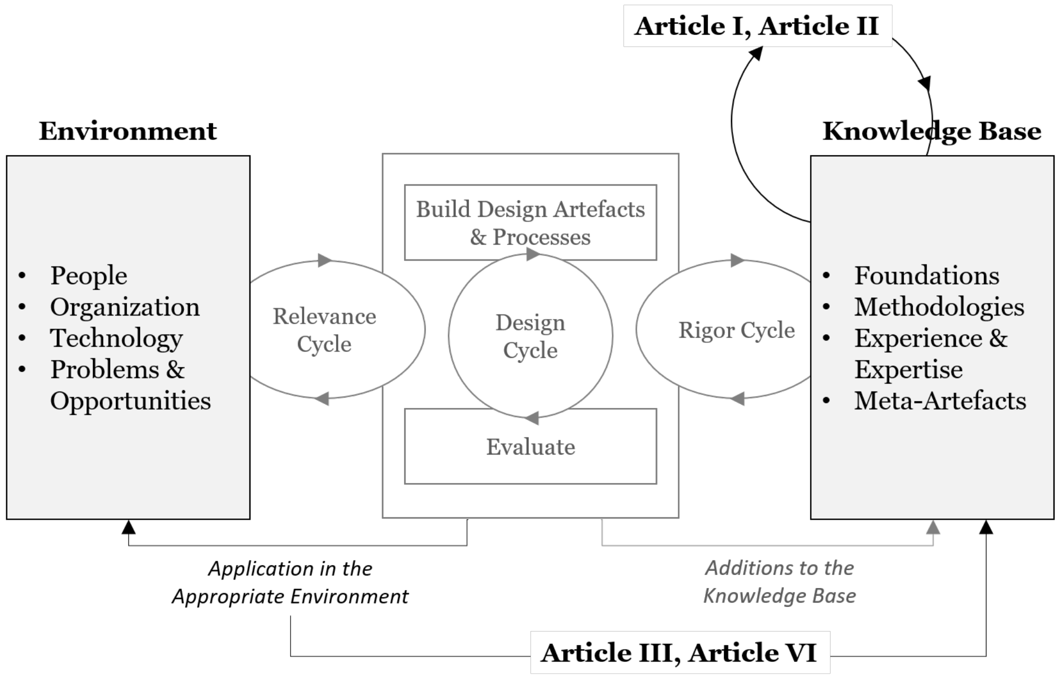

Figure 1. Conceptual Research Framework (DSR Model Adopted From Hevner et al. 2004; Hevner 2007)

Articles I and II are positioned in this context to improve fundamental knowledge of the accessibility theory and the factors that influence the accessibility that scientists gain as a premise for constructing and developing accessibility. The material in Articles I and II are based on prior studies that include empirical research. Articles III and IV are positioned to improve the fundamentals. In addition, the studies also concern matters related to the appropriation of the environment and the needs of content creators in the promotion of accessibility, which has been identified to be limited in the literature.

In the first article, I explain what accessibility is and how it is interconnected to usability and user acceptance. I reviewed selected theories representing the components that the definition of accessibility contains. This paper contributes a richer descriptive theory of accessibility to be used in IS artefact design.

The second article synthesises the existing knowledge on factors that affect accessible IT artefacts from a user perspective (including variables in human abilities), IT management perspective and development perspective. In this paper, we conducted a systematic literature review. This paper contributes to the knowledge of the factors and solutions in management, developer and user level affecting the realisation of accessible IT artefacts. This study also identifies the lack of prescriptive knowledge addressed to content creators who play a crucial role in the production of accessible information.

The third article addresses the lack of prescriptive knowledge to produce accessible information. In this study, we complement prescriptive knowledge by designing online text accessibility heuristics for the use of content creators who create the actual content for IT artefacts. The study is performed with a design science research methodology. The object of this study is scoped to text format content since it is the most used format on the web.

The final article proposes an implementation model for text accessibility heuristics created in Article III. As the first requirement for the design principle is the implementer aspect (Gregor et al., 2020), we considered the cognitive process theory of writing (Flower & Hayes, 1981) and aligned the heuristics in appropriate order to make them more efficient to implement.

1.4 Structure of the Dissertation

This dissertation is structured as follows. First, I describe the background, which includes the motivation for this dissertation, the aims, and the conceptual framework for how the articles of this dissertation are positioned in design science. Next, a brief summary of Articles I–IV is presented, followed by a synthesis of their key results that answer the research questions of this dissertation. Then, the contributions to research and practice, as well as the objectivity and trustworthiness aspects, are discussed, followed by future research suggestions. Finally, the original articles are presented.

2 SUMMARY OF THE ARTICLES AND A SYNTHESIS

This chapter presents a brief summary of each article included in this dissertation. These summaries contain an introduction to the problem, followed by a description of the utilised methods. Then, I present key results. Finally, the key results are synthesised to answer the research question.

2.1 Article I: Explaining Accessibility: Possible Variables in Users' Abilities, Tasks and Contexts in IT Artefact Use

The literature has found it challenging to define the interconnection and overlap between accessibility and usability. This has led to scientists arguing about the scope of accessibility, making the understanding of accessibility and the exchange of knowledge in the community inconvenient. Ambiguous interconnection may lead to an inaccuracy in the evaluation of these features. However, IS and HCI researchers should strive to ensure that technologies and practices are as accessible as possible so that the developed systems and technologies do not discriminate against anyone. Nevertheless, there is a dearth of models describing the components of accessibility and their variables. Such a model is necessary to enable researchers to position their target more accurately and identify the related factors. To be precise, the contributions of this article are as follows: to help researchers recognise the relationship between the components consisting the concept of accessibility; to define and align the intended research focus related to human ability with the overall picture of accessibility; to gain an understanding of the variables of human abilities related to IT interactions; and to establish how task characteristics and the context of use affect interactions. In this article, I developed a theoretical description of accessibility that describes the structure of its components and the relationships between them in an IT use context. I drew upon the theories beyond HCI, task performance and context to posit the human abilities in IT use. The discussed human abilities were drawn from the ontologies of the International Classification of Functioning, Disability and Health (ICF) by the WHO.

Method: In this article, I address these questions: *What is the scope of accessibility, and how is it interconnected with usability?* and *What are the possible variables in the components of accessibility?* The ultimate objective of this article is the development of a new theory without theory testing. Therefore, it aims to contribute a foundation for further research into the domain of accessibility. I first based the premise of the study on the ISO Standard (ISO 9241–

11:2018) definition of accessibility consisting of the following components: interaction with IT artefacts, human abilities, identified goals (i.e. user tasks) and the context of use. Next, I reviewed selected kernel theories related to these components. I extracted the knowledge related to constructs, statements of relationships and the scope. Then, I synthesised the following theories of each component: human abilities: the International Classification of Functioning, Disability and Health (ICF) agreed upon by the World Health Assembly in 2001 (WHO, 2013), Cattell-Horn-Carroll's (CHC) theory of intelligence within cognitive abilities (McGrew, 2009), task performance by Norman, (1986), the context of use (McKay et al., 2012) and the theory of HCI by Schomaker and Hartung (1995). With these theories and their related studies, I illustrated the Accessibility Model (AM) that describes the construct of 'accessibility', including its components, variables, processes, and their relationships. Then, I demonstrated how the AM is positioned compared with technology acceptance models. Finally, the AM was discussed and compared with prior models.

Findings: As a result, the AM (Figure 2) is presented. Moreover, it is argued that accessibility is a moderating variable between system features and usability. Thus, accessibility is a major determinant of user acceptance. The model delivers a more detailed description of accessibility. The AM illustrates the cycle of information exchange between the user and the computer, which should be rotated as long as the user finally reaches the information. If this rotation ends or is interrupted by a mismatch between the user's abilities and the computer output media or computer input modalities, the features of the IT artefact or the formalisation of the information become inaccessible.

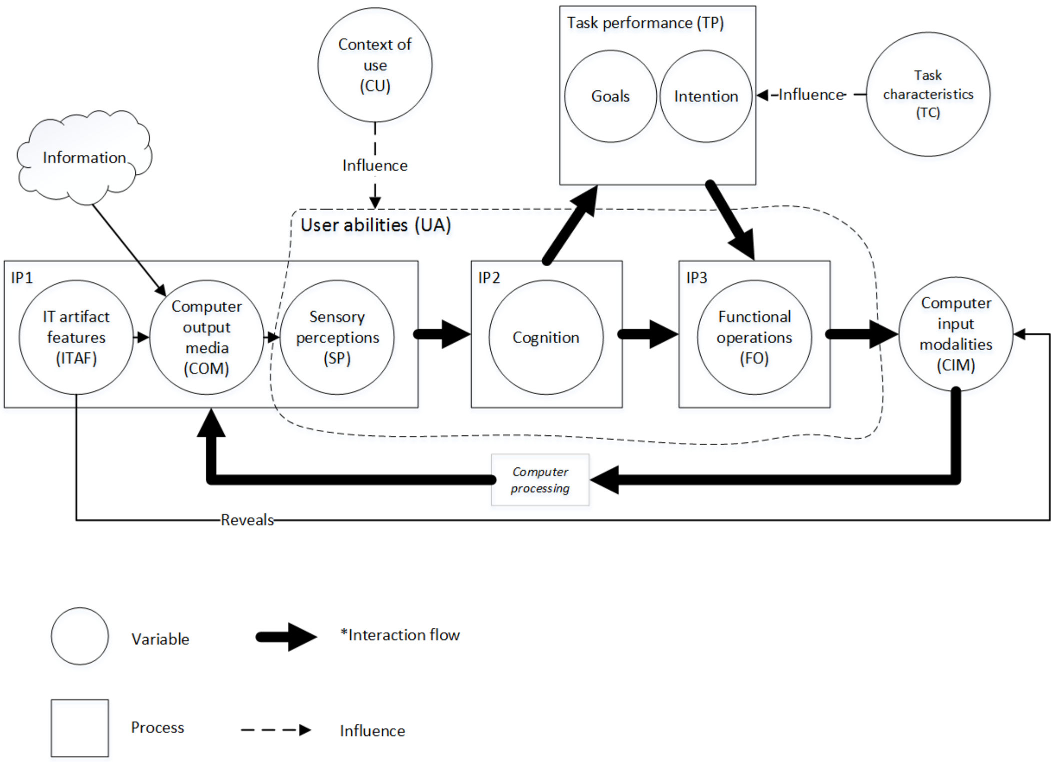

Figure 2. Accessibility Model (Article I).

The AM describes the variables and the relationships among the following components: 1) user abilities; 2) interaction; 3) IT artefact features; 4) information; 5) tasks; and 6) context of use.

(1) *User ability* is a variable that depends on the individual. It includes sensory perception, cognition and functional operations. Sensory perception constitutes abilities of sight, hearing, touch, smell, taste and balance. Cognition comprises abilities in focusing attention, memory, thinking and speed of processing, reading and writing, mental functions of language, calculating and quantitative knowledge, solving problems, making decisions and reaction speed, psychomotor functions and sequencing complex movements and speed, emotional functions, perceptual functions, higher-level cognitive functions and domain-specific knowledge, experience of self and time functions, and comprehension-knowledge. Functional operations include abilities in movements, voice and sight.

(2) Interaction is a process that includes three sub-processes. First, the user's sensory perception perceives the IT artefact features that computer output media present and delivers the information to the next process. In the next process, the user's cognition interprets and organises the perceived data and gives commands to the user's functional operations. The user's

functional operations receive the commands from cognition and act with computer input modalities, such as movements, force and sound, which are also presented via IT artefact features.

(3) *IT artefact features* include the IT artefact's content, presentation style, interaction style and structure. Computer output media presents these features, and it has visual, auditive, tactile, olfactory, gustatory or vestibular modalities.

(4) Information is a conceptual component of accessibility. It is the key component. It contains the message that its provider wants to convey. Information can be presented through various computer output media. In addition, the information also has its own quality.

(5) *Tasks* include the user's perceptual and cognitive abilities. In this performance, the user first perceives and recognises the system stage; second, the user interprets and understands the meaning of the message; third, the user evaluates the system stage and understands the consequences with respect to the established goals and intentions; finally, the user engages in physical activity. The task itself may be complex, motivating or engaging, among others, which are characteristics that influence task performance.

(6) Context of use varies based on environmental factors, users' emotional state, socio-cultural factors and socio-technical factors, whereby cultural, political, sociological and historical aspects of context influence users.

2.2 Article II: Factors Affecting Accessibility of IT Artifacts: A Systematic Review

In the past two decades, the awareness, techniques and methods for creating accessible IT artefacts have improved. However, as previous studies have often addressed the factors characterising a particular group or population, the overall picture of the factors affecting the accessibility of an IT artefact in development and use is fragmented and, thus, vague. Accessibility problems may occur either at an individual level where IT artefact features do not support people's abilities to use it or at the organisational level where management support and developers' accessibility knowledge play a crucial role. These potential problems arise in areas that comprise the core of IS research. Therefore, we conducted a systematic literature review to gain in-depth knowledge of the overall factors that influence the realisation of an accessible IT artefact, including factors related to users, developers, management and the IT artefact itself.

Method: In this study, we conducted a systematic literature review to describe and summarise existing knowledge related to our research question from the selected database. We exploited the techniques of Kitchenham and Charters (2007) and Okoli (2015) to design a research protocol and conduct our study in four phases: 1) planning the review phase; 2) conducting the review phase (including three steps); 3) data extraction phase; and 4) data synthesis phase.

For this study, we targeted research and empirical papers published in high-level and two-tier IS and HCI journals and conferences. We selected a ‘basket of eight’ set of IS journals recommended by the Association for Information Systems (AIS). These include the following: *European Journal of Information Systems*, *Information Systems Journal*, *Information Systems Research*, *the Journal of Association for Information Systems*, *the Journal of Information Technology*, *the Journal of Management Information Systems*, *the Journal of Strategic Information Systems*, and *Management Information Systems Quarterly*. Next, we selected the following two-tier IS journals ranked by the Chartered Association of Business Schools (‘Academic Journal Guide 2021’, 2021): *Decision Support Systems*, *Government Information Quarterly*, *Information and Management*, *Information and Organization*, *Information Society*, *Information Systems Frontiers*, *Information Technology and People*, *International Journal of Electronic Commerce*, *Internet Research*, *Journal of Computer-Mediated Communication*, and the *Journal of the Association for Information Science and Technology (JASIST)* (formerly the *Journal of the American Society for Information Science and Technology*). Then, we selected a set of HCI journals recommended by the AIS Special Interest Group in HCI: *AIS Transactions on Human–Computer Interaction*, *ACM Transactions on Computer–Human Interaction*, *the International Journal of Human–Computer Studies*, *Human–Computer Interaction*, and *Computers in Human Behavior*. Finally, we included proceedings from *the International Conference on Information Systems*.

We conducted the search for articles published between the years 2000 and 2020 with the search keyword ‘accessibility’, which we expected to be featured in the article’s title, abstract or keywords. We excluded literature reviews, editorials, opinions, commentaries and short papers. The review protocol contained three steps. First, we evaluated articles based on the title, abstract and keywords. Next, we evaluated articles by introduction and conclusion. Then, we evaluated articles based on the full paper. Finally, 82 articles remained relevant to our research question, namely, *What factors cause accessibility problems, and what solutions* *does the literature suggest?* We used the ICF agreed upon by the WHO to classify what human abilities the selected articles addressed.

Findings: After coding 82 articles, we identified the factors that affect accessibility in management, development and individual level. By synthesising these factors, we produced a model (Figure 3) that illustrates the domains and their roles and interaction with other domains as factors that need to be addressed to create accessible IT artefacts.

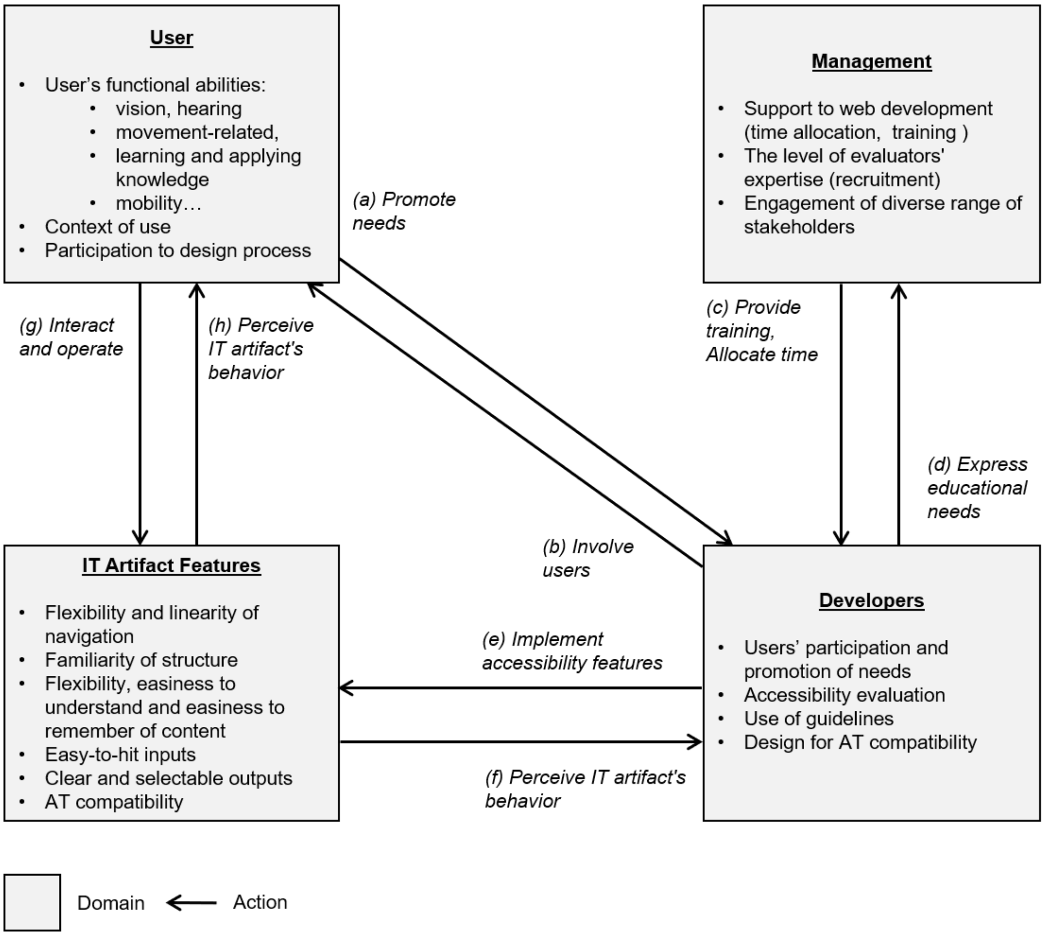

Figure 3. Key Factors and Solutions Affecting Accessibility (Article II).

At the management and development level, managers, developers and users play an important role in promoting accessibility. Management can influence the development of accessibility by providing training to developers, recruiting experts to assess accessibility, allocating time and resources for the development of related projects and engaging stakeholders such as copywriters, policymakers and educators to promote accessibility. Developers should engage users to promote their actual needs, including users with disabilities, their caregivers and non-disabled users. They should be involved at least in planning, testing and evaluating processes using appropriate methods such as participatory design, user-sensitive design or user-centred design. Users should promote their actual needs related to their abilities and the context for that particular IT artefact under development. To improve the identification of accessibility errors and understanding of problems, accessibility evaluation should combine automatic inspection tools that compare the target against accessibility guidelines such as WCAG requirements, manual evaluations such as user testing, or investigations of event logs. To increase developers' awareness of accessibility and its integration into IT artefacts, the use of accessibility guidelines appropriate for the content (e.g. WCAG for web content or game accessibility guidelines for games) is necessary. Furthermore, usability, user experience and privacy guidelines should be integrated with accessibility guidelines to improve other features and identify if the integration shows any contradictions.

As a result of our analysis, we identified the key factors that cause accessibility problems for a particular user group. Users' functional abilities, including sensory abilities, such as seeing and hearing, movement-related abilities, cognitive abilities like the ability to learn and apply knowledge, mobility, and so on, set certain design requirements for the features of IT artefacts. These requirements relate to the IT artefact navigation, structure, content, input method or output method. To meet these needs, IT artefact features should be as follows: navigation should be solo and linear, that is, straightforward and navigation should also be modifiable and include a function that allows skipping it. In addition, the names of links and menus should be described informatively, that is, tell where the link leads. The structure should be familiar, in which case its elements are in consistent locations. In addition, the purpose and goal of the functionalities should be clearly expressed. Content should be easy to understand and easy to remember. It should contain features that allow the removal of visual content and re-organises relevant content in the first place unless it has already been done at first. Any visual information such as graphs should also be presented as a natural language. Text should be written using coherent and everyday terminology utilising a bilingual approach. In listings, word recognition should be facilitated with the help of icons. A level structure should be applied, or a guidance for tasks should be provided. IT artefacts should help users hit a target with a pointing device (e.g. mouse). For this endeavour, for example, a virtual cursor can be used to indicate the cursor area. IT artefacts should give clear feedback for focus and contain multiple modalities in output formats, such as text, audio and images to share information selectable by the user. Finally, as mentioned earlier, developers should build IT artefacts in a way that their features are compatible with AT.

2.3 Article III: Designing Heuristics for Accessible Online Text Production

Content creators are one of the groups that have a crucial role in the promotion of accessibility. Through them, the actual content—text, videos, audio, etc.—is generated or updated into an IT artefact (e.g. website). Despite the increasing amount of audio-visual content on the web, the most common format is still the textual format. Existing guidelines for accessible text content creation are either focused on complying with accessibility problems of a certain group or population, such as people with dyslexia or are too technical and inappropriate for content creators. Content creators are a group of practitioners who may have various backgrounds in technical expertise, but existing guidelines such as the WCAG are difficult to apply in content creation because they consist mainly of techniques to improve the programming of a website. In practice, content creators are struggling with the question of how to create accessible text content. Therefore, in Article III, we addressed the question *What design heuristics can support content creators in producing accessible online texts?* We aimed to contribute improvements for the guidance of accessible text production that is designed by considering first the possible accessibility problems that various groups or populations may face. Then, we considered the needs of content creators so that the guidance is easy to use and understand for them. In this article, we propose heuristics for accessible online text production, which are meant for content creators in public organisations to enable text accessibility for people with disabilities on a website. The heuristics can also be used as a self-assessment tool in evaluating online texts.

Method: We performed this study with a design science approach to contribute improvements to accessibility guidance for online textual content by creating a proposal for accessibility heuristics for text production. In this project, we addressed various issues, particularly for content creators, to develop a suitable tool for them to promote text accessibility. To achieve our aims, we adopted the design science research methodology (DSRM) process model by Peffers et al. (2007). We performed DSRM in three conceptual phases: 1) problem identification and objective definition; 2) artefact design; and (3) artefact demonstration and evaluation.

In the first phase, we conducted a literature review to collect prior guidance for text accessibility and identify inadequacies in existing guidelines. We performed the search on Google Scholar with a date range of 2000–2019 using the search term ‘accessibility heuristics’, which returned 387 papers, and the search string ‘text’ AND ‘accessibility heuristics’, which returned 187 papers. We included only papers with a search term/string stated in the title, abstract or keywords. We analysed 34 remaining papers published in a journal or a conference based on the full article. Finally, we included only papers that provided guidance relating to text accessibility. We also added WCAG and ICT for Information Accessibility in Learning (ICT4IAL) manually. Then, we analysed seven papers and integrated all guidance relating to text accessibility into the emergent categories that they provided. We identified that guidance was related to the text format, structure or content. After the analysis, we found 14 factors that improve text accessibility based on prior studies. We used these factors as reusable items to formulate a candidate version of the heuristics, which we evaluated and enhanced in a second phase.

In the second phase (artefact design phase), we had two design iterations. First, we established a workshop to formulate the heuristics and improve their usability and utility. We held the workshop with 31 university master-level students from the IS and technical communication programme. The students were regarded as intermediate content creators. In the workshop, we asked the participants to evaluate the web content of a Finnish public organisation's website heuristic by heuristic. We asked them to comment on each heuristic in terms of understandability, clarity of content, flawlessness and anything they considered important. Finally, they summarised their findings in a questionnaire that we analysed using thematic content analysis (Zhang & Wildemuth, 2017). In the second design iteration, we invited three content creators from different public organisations, namely, university, governmental agency and association, under the same accessibility legislation to an interview. The participants had four to 15 years of work experience in content creation. The purpose of this interview was to evaluate the feasibility of the heuristics. The data were collected using a semi-structured theme interview with the following themes: the current situation regarding accessibility in the relevant organisation, the content of the proposed heuristics, and the feasibility of the heuristics.

The third phase (artefact demonstration and evaluation) was conceptual. In this phase, we performed the evaluation of the proposed heuristics, first, during the workshop as an *ex-ante* evaluation (Sonnenberg & vom Brocke, 2012; Venable et al., 2016), and second, during the interviews as an *ex-post* evaluation (Sonnenberg & vom Brocke, 2012; Venable et al., 2016) to confirm the proof of concept (Gregor & Hevner, 2013). For framing the evaluation, we applied the evaluation framework (why, when, how and what to evaluate) proposed by Venable et al. (2016). In total, we conducted assessments concerning validity, utility quality and efficacy (Gregor & Hevner, 2013). In the workshop, the participants evaluated the heuristics in terms of learnability, utility, memorability, flawlessness and consistency with open-ended questions. Then, to verify the expected value (Gregor & Hevner, 2013) for actual users (Gregor & Hevner, 2013; Venable et al., 2016), we evaluated the heuristics' importance, feasibility and utility to practice (Sonnenberg & vom Brocke, 2012) with participants during the interview.

Therefore, during our research process, we had three versions of the heuristics. The first version was based on the results of the literature review, the second was developed with the results of the workshop, and the third (final version) was developed with the results of the interview.

Findings: Our contributions are as follows. First, our analysis of prior guidance for text accessibility revealed that none of the selected guidelines were comprehensive compared with one another. For example, among prior guidelines, there was no such instruction that also repeats in all other instructions, and there were instructions that manifested only once. Moreover, we found that every instruction was related to formatting, structuring or content, which enabled us to categorise the heuristics. Second, as a result of two design iterations in Table 1, we propose a total of 15 heuristics for online text production for content creators.

Table 1. Online Text Accessibility Heuristics (Article III)

Heur.	Instructions	Explanation	Category
H1	Emphasise verbally the important points you want to make. You may also use bolding or colours for emphasis, but do not use bolding to indicate titles.	The reader may only listen to your written text, in which case the emphasis or use of colours is ignored.	Formatting
H2	Use font sizes 18–26 pt. for online content and 22–26 pt. for headings, depending on the heading level.	Larger font sizes improve online readability.	Formatting
H3	Favour sans serif fonts, such as Verdana or Arial.	A sans serif font is simple, so it is clear and easy to read online. Verdana is one of the most popular and aesthetically pleasing fonts designed for on-screen viewing. Arial is slightly faster to read.	Formatting
H4	When you list things, use bullets or numbers. Try to avoid using multi-level lists.	By using bullets for main topics, you help readers scan your content and identify key areas. Multi-level lists can be confusing.	Formatting
H5	Make the text airy. Adjust the line and paragraph spacing.	Readability increases if the line spacing is 1.5 and the paragraph spacing is twice the font size.	Formatting

Heur.	Instructions	Explanation	Category
H6	Align text to the left.	Text aligned to the left margin makes it easier to find the start of the next line.	Formatting
H7	Pay attention to the contrast between the text and the background.	To improve readability, you may use light tones of warm colours for the background.	Formatting
H8	Use headings (H1, H2, etc.) consistently. Avoid sub-sub-headings (e.g. 1.1.1.1).	Do not use headings to increase just font size, as headings are meant to divide content into meaningful sections. Headings are important for screen reader users to navigate a page according to its headings.	Structuring
H9	When you add images using information, explain their message in the textual content. This way, the screen reader user gets the same information, too.	If the image is not described in the text content, you can describe it in about 100 character-long alt text (in image properties). When a screen reader finds an image, it reads out the content of the alt tag.	Structuring
H10	Separate links from other content with underlined blue colour, and use text that properly describes where the link will go.	Name links according to the action that will occur or the place or name of the website to which the user will be taken (e.g. ‘Go to calendar’).	Structuring
H11	Use clear and simple language.	Use common everyday words and avoid the use of jargon whenever possible.	Content
H12	Provide the full meanings of abbreviations and acronyms at their first use.	Abbreviations and acronyms should be defined in full. The exception is established abbreviations, which may not even be recognised when written out (e.g. DVD).	Content
H13	Provide the most relevant information first. For long texts, provide a short summary of the content at the beginning.	The content is easier to perceive when the most important information is placed on the top of the page.	Content
H14	Prefer short sentences and avoid complicated sentence constructions.	Short sentences help readers understand the content better. Express one idea in one sentence.	Content
H15	Use *you* when addressing the reader.	This way, readers feel that the text is speaking to them.	Content

The design iterations and the evaluation of the heuristics demonstrated that they are clear, easy to use and useful for content creators. The effect of the content of the heuristics is justified as the foundation of the heuristics are studies from the literature. Based on these, the proposed heuristics consider the needs of people with dyslexia, the needs of people experiencing difficulties in understanding content or cues (cf. H15; H9; H1), people with limited memory (cf. H12) and those with difficulties in perceiving visual information (cf. H1; H9; H12).

2.4 Article IV: Implementation of the Online Text Accessibility Heuristics

In this book chapter, we propose an implementation model for the online text accessibility heuristics presented in Article III. The heuristics are developed for content creators to serve as their guide in accessible text production. Overall, based on the nature of heuristics, they provide principles that serve as guides in taking action towards procedures, ideas or results in general. These 15 heuristics are listed by category, including category formatting, structuring and content. This categorisation will help the implementer find the appropriate instructions for each area easily. However, the listing has not considered the implementer's writing process, which may lead to inconsistency. Therefore, in this study, we addressed how the heuristics should actually be implemented and what the optimal sequential order should be in applying these heuristics during the writing process. As the heuristics are meant to guide how text should be written, we compared and aligned the heuristics to the cognitive process theory of writing by Flower and Hayes (1981).

Method: We selected the cognitive process theory of writing by Flower and Hayes (1981) as a fundamental theory with which to compare the heuristics. We retrieved the theoretical elements that the writing process contains. Then, we compared which heuristics belong to which part of the writing process. By analysing the content of the heuristics and the writing process, we aligned heuristic by heuristic to the process theory of writing and discussed their influence on a writer's task environment and a writer's knowledge about his/her audience.

Findings: We first identified the heuristics as they are proposed to create alignment between the writer's decision to reach the audience in the web context and the actual writing process. This means that the writer makes the decision to use the heuristics to reach the audience. Moreover, the decision to use the heuristics refers to the writer's intention to promote accessibility. Therefore, it influences the writer's goal settings. In addition, heuristics also influence the writer's knowledge about the audience at that point as heuristics inform the writer how people benefit from accessibility. We aligned the heuristics with the writing process proposed by Flower and Hayes (1981) (Figure 4).

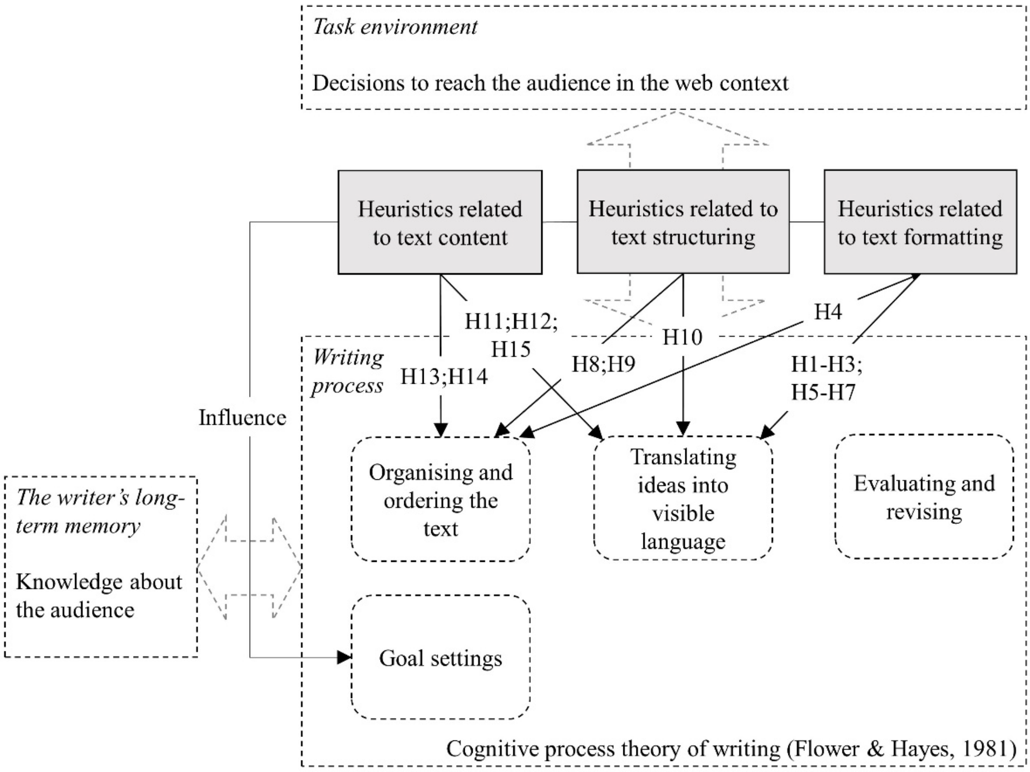

Figure 4. Online Text Accessibility Heuristics Implementation Model (Article IV).

Based on our analysis and reasoning, Figure 4 illustrates how the heuristics are aligned between the writing process and the task environment. In principle, we recommend considering the content first, then the structure, and finally, the formatting.

The writing process starts with organising and ordering the text. For the content of the text, these include the identification of important ideas, such that the most relevant information will be provided first (H13). Then, these ideas should be formulated by using short sentences and avoiding complicated sentence constructions (H14). Next, the ordering contains considerations on how to structure the text. For this, we recommend using headings (Heading 1, Heading 2, etc.) and consistently avoiding sub-sub-headings (H8). Then, we recommend explaining all the information contained in images in the textual form (H9). Finally, when ordering the text, we recommend considering if the upcoming text will contain the elements that require formatting. For instance, if the writer lists things, then bullets or numbering should be used (H4).

Next, the writing process translates ideas into visible language. Again, we recommend considering first the content, then the structure, and finally, the formatting. The content of the text should be written using clear and simple language (H11), providing the full meanings of abbreviations and acronyms at their first use (H12) and using the active voice (you-form) if addressing the reader (H15). Next, if links are used, they should be considered part of the structure because they form part of the page navigation structure. We recommend separating links from other content with underlined blue colour and using text that properly describes where the link will go (H10). Finally, the formatting of visible text should be considered. We recommend emphasising verbally the important points that the writer wants to make. Bolding or colours for emphasis can be used, but bolding should not be used to indicate titles (H1). The text should be written using font sizes 18–26 pt. for online content and 22–26 pt. for headings, depending on the heading level (H2), and favour Sans Serif fonts, such as Verdana or Arial (H3). Then, the line and paragraph spacing should be adjusted to make the text airy (line spacing is 1.5, and paragraph spacing is twice the font size) (H5). The text should be aligned to the left (H6), and the contrast between the text and the background (H7) should be considered. As a result, we suggest implementing the heuristics in the following order: when organising and ordering the text, it should be H13, H14, H8, H9 and H4, whereas when translating ideas into visible language, it should be H11, H12, H15, H10, H1, H2, H3, H5, H6 and H7.

2.5 Synthesis of the Articles

In this chapter, I synthesise the key findings of Articles I–IV to answer the research question *What are the key determinants of knowledge to form design theories for achieving accessible IT artefacts?*

The universal nature of accessibility creates an exception to the target group. Typically, IT artefacts are designed for certain groups or populations considered as users. In this dissertation, these target groups are divided based on human-related abilities that people may or may not have. Generally, target groups can also be divided into other terms, for example, by their experience of using computers (novice, intermediate, expert and occasional users). However, the universal approach does not delimit the target group, meaning that IT development should consider the broadest possible range of abilities that users may or may not have in the use contexts.

Together, the articles demonstrate the knowledge needed to create design theories for the further use of designing IT artefacts for various tasks and contexts in attempting to achieve accessibility for all users. This knowledge can be deduced from the following determinants of knowledge: assumptions about users' abilities, users' actual needs and factors in the development chain (Figure 5).

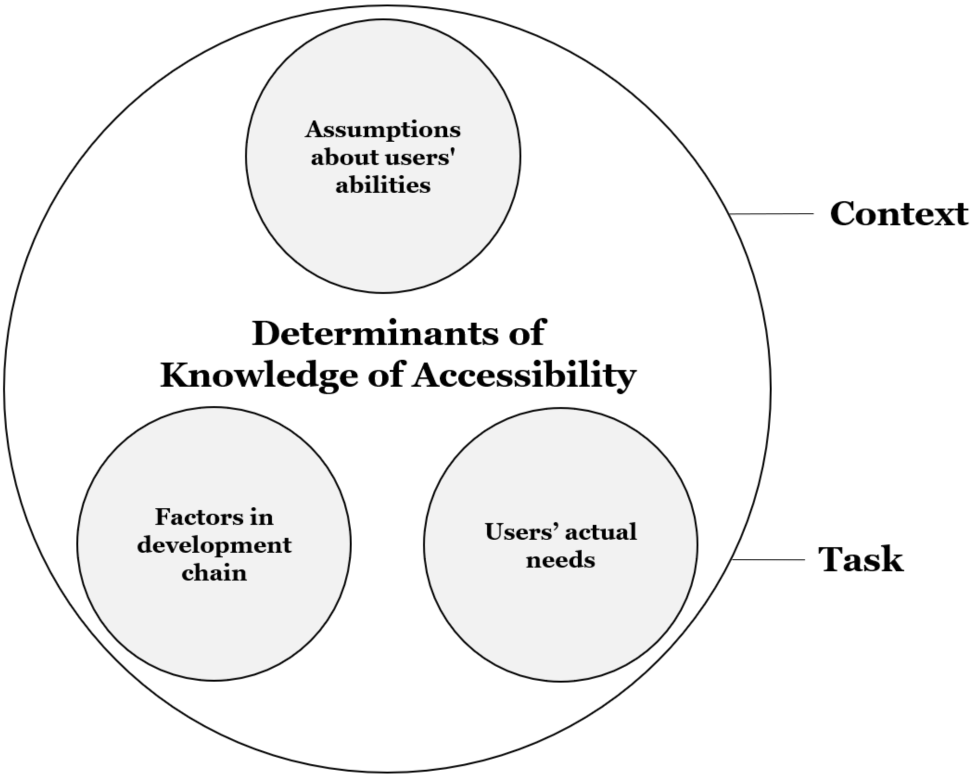

Figure 5. Determinants of Knowledge of Accessibility

Assumptions about users' abilities to use IT artefacts: Article II combines previous knowledge of the possible accessibility-related factors that pose or can pose a barrier to IT artefact use. This knowledge includes users' interactions with IT artefacts involving human processes related to sensory perception, cognition and functional operations, which are presented in Article I. These processes require user abilities that vary depending on user characteristics. By referring to the ICF, Article I combines all possible variables in user abilities that need to be addressed in terms of accessibility. However, designers need to build the interface so that users' abilities and possible lack thereof are considered in each interaction process. Thus, it must be assumed that the user does not have all the abilities in these processes. In practice, this means that the information—the message that its provider wants to convey—is presented using computer output media (text, images, videos, etc.), such that users can perceive them with some of their sensory abilities (sight, hearing, touch, etc.) (Article I). Furthermore, the content of the information should be presented in a style through which users can interpret and organise the perceived information with their cognitive abilities (focusing, memory, thinking, etc.). Article III shows an example of how the text content should be presented to improve online text content accessibility.

Therefore, when designers build IT artefacts, they should either build each part in such a way that it does not pose an accessibility problem or provide an alternative route for the user to obtain the same information. However, as stated in Article II, the accessibility principle does not allow certain groups of users to have a completely separate interface, but solutions that address accessibility problems for certain groups of users should be integrated into one solution that might be challenging in some cases, as these may influence other features. In practice, this means that some solutions solve the accessibility problems of some users but not others. To address this challenge, Article I proposes a description of accessibility, its constructs, and their relationships, which researchers can use to examine their current accessibility problem and see its relationships and possible related variables. This is meant to enhance the rigorousness of accessibility-related research. Article I shows that accessibility can be considered a moderating variable between systems features (independent variable) and perceived usefulness and perceived ease of use (dependent variables).

Therefore, to enable designers to identify the actual needs of users for whom a planned IT artefact is intended, the tasks, contexts of use, and knowledge of users' actual needs are needed.

Users' actual needs for actual use: According to the systematic literature review conducted in Article II, accessibility research states that user participation is vital. The creation of accessible IT artefacts requires more than prior knowledge of the possible needs or the use of guidelines. This is because every IT artefact has certain tasks and contexts of use. User participation is also more than just eliciting users' actual needs. It involves possibilities of detecting innovations to tackle accessibility problems and identifying new realistic possibilities to create a better experience for actual use. Accessibility scholars suggest involving users from the target groups: people with disabilities, their caregivers and even non-disabled people. User participation with methods such as participatory design, user-sensitive inclusive design or user-centred design is generally accepted and respected in accessibility research (Gerling et al., 2016; Vollenwyder et al., 2019). According to Mack et al. (2021), the median sample size for participation in previous accessibility studies is 13 participants. Furthermore, user participation influences developers' motivations and intentions to promote accessibility. In principle, the design for accessibility should address the actual needs of every user group. In Article I, these user groups are divided based on users' functional abilities by referring to the ICF by the WHO (2002): vision, hearing, movement, learning and applying knowledge, and mobility. In user participation, users interact and operate with IT artefacts that are targeted for development, and they perceive the IT artefact behaviour. Then, they promote their actual needs relating to the IT artefact to the developers. Article II shows these interactions among users, development, management and IT artefacts as a crucial factor in the realisation of accessibility.

Factors in the development chain: Article II presents the activities and processes related to accessibility in IT development, including management and development. Article II also demonstrates that accessibility guidance for content creators has been allocated less attention in the literature. Article III presents heuristics as a guide on what accessibility adjustments content creators should consider in text contents. Article IV enhances the heuristics presented in Article III to make them more efficient to use. Thus, Articles II, III and IV all show that the IT development chain contains the following domains: users, management, development and content creation. The foregoing have determinant roles in the realisation of accessibility. These roles are as follows: users participate in IT projects and promote their actual needs, as stated previously; managers support the web development, including training, time allocation, recruitment and engagement of other stakeholders; and developers communicate with managers about their educational needs, communicate with users, and implement accessibility features into the IT artefact. The implementation includes evaluation, use of guidelines, design for AT compatibility and addressing users' actual needs. Content creators are responsible for content accessibility. Article III addresses text content accessibility and proposes heuristics as tools for content creators to produce accessible text and evaluate it. Article IV enhances the efficiency of heuristics as they are fitted into the writing context.

Context and **Task**, as presented in Figure 5, are the variable factors that need to be considered and designed for each IT artefact, depending on the case. However, there are factors that comprise overall concerns. The task performance includes the following user interaction processes: the users evaluate the mental results of what they have interpreted and organised from the perceived data during the interactions against the goals of the task and their own intentions to perform the task. Specific characteristics such as simplicity, motivating, engaging, and others can be designed for the task, which can influence its execution. These characteristics can have a positive or negative influence on task performance. The requirements regarding the real context of use should be identified during the users' promotions of their actual needs. As in the task design, the overall factors of contextual varieties should be considered. The context varies in environmental factors, users' emotional state, socio-cultural factors and socio-technical factors, whereby cultural, political, sociological and historical aspects of the context influence users.

3 DISCUSSION AND CONCLUSIONS

Accessibility refers to the fact that the IT artefact (e.g. website, user interface or application) is designed and built in such a way that each user is able to use it regardless of his/her abilities or disabilities. Accessibility research, among other goals, attempts to gain prescriptive knowledge of the design, methods, techniques and practices that practitioners in web development can use to create IT artefacts that are accessible to all. The problem is that despite improved awareness and development in the past two decades, many users still encounter accessibility barriers (Brajnik et al., 2011; Martins et al., 2017; Santana & Baranauskas, 2015; Vollenwyder et al., 2019). However, accessibility is a basic human right (United Nations, 2006).

The aim of this dissertation was to complement this knowledge with the determinants of knowledge of accessibility so that research would have better premises to form design theories for the use of practitioners attempting to create accessible IT artefacts.

This dissertation contributed to an in-depth understanding of the concept of accessibility, its components and the relationships between these components. Moreover, it describes the relationship between the concepts of accessibility and usability under the technology acceptance behaviour. Then, this dissertation collated the factors that create possible accessibility problems for users categorised by the human abilities defined in the ICF (WHO, 2021). It identified the factors in IT management, development and the IT artefact itself that affect the realisation of accessibility. This dissertation also improved and complemented accessibility knowledge in the IT development chain by proposing online text accessibility heuristics for the use of content creators, a topic that has been found to be studied at a lesser degree. Summarising the contributions of Articles I–IV, three abstracted determinants of knowledge of accessibility are derived that could help researchers form prescriptive knowledge for the use of practitioners to achieve accessible IT artefacts. This means that researchers could identify possible variables and relationships, as well as affecting factors related to human abilities, management, development, content creation, tasks and context of use.

In the following sections, I discuss how this dissertation complements existing knowledge and elucidate the contributions of Articles I–IV to research and practice.

3.1 Theoretical Implications

The AM presented in Article I extends the HCI model by Schomaker and Hartung (1995) with more detailed descriptions of human cognitive abilities, factors related to task performance and context. The CHC theory by McGrew (2009) and the ICF classifications of cognitive-related abilities (WHO, 2021) are unified and included in the model. Furthermore, the model shows the relationship between human interaction processes and task performance (Carroll, 1993; Norman, 1986). The interconnection between accessibility and usability can be found between system features and perceived utility and perceived ease of use. In technology acceptance models, the features of the system include usability (independent variable). In terms of acceptance, the system usability affects the perceived usefulness and perceived ease of use (dependent variables), which influence the attitude towards using the system (Davis, 1993; Davis et al., 1989). However, usability includes features such as learnability and memorability that require the user's cognitive effort. Thus, with appropriate adjustment of accessibility, these features can be made possible for persons whose abilities have been considered in IT artefact design. Thus, accessibility is a moderating variable between system properties and perceived usefulness and perceived ease of use. In the AM, a description of variables gives the premise for design theories that concern all possible human abilities. In addition, the AM lists the task and context factors affecting the interaction between humans and computers. Thus, the AM guides the design of an IT artefact that considers possible variables in people's abilities and helps researchers identify the affecting variables associated with the target (tasks and context) to be studied.

In Article II, we conducted a systematic review. This review combined previous knowledge of the factors that create accessibility barriers to the use of IT artefacts and classified the features of IT artefacts where these problems arise. We collated the data based on human abilities classified by the ICF (WHO, 2002). With this review, we also mapped out the factors related to management and development that have an impact on the realisation of accessibility. Referring to selected journals, we found that there were few studies on the same subject, particularly in the IS discipline. Prior accessibility-related systematic literature reviews presented methods and techniques recommended for use in different phases of software development (Mack et al., 2021; Paiva et al., 2021). The systematic reviews by Campoverde Molina et al. (2020), Ordoñez et al. (2020) and Zhang et al. (2020) all indicated that the WCAG requirements are perceived as *de facto* to improve accessibility. The WCAG requirements certainly offer a great help for web practitioners to improve accessibility. However, some of the primary studies included in the review in Article II revealed that using WCAG only to improve accessibility is not sufficient. Petrie et al. (2003) and Vigo and Harper (2013) also claimed that only around half of the accessibility problems encountered by blind people are covered in the WCAG. Article II described what design solutions had been suggested by primary studies to address these critical barriers.

In Article III, we collected and reviewed seven prior heuristics or sets of guidance for web content accessibility that were developed in a workshop with students and, thereafter, with content creators. This study contributed combined heuristics particularly geared towards the creation of text content accessibility that were improved and tested empirically. Comparing the proposed heuristics to the prior seven heuristics, the former cover the needs of people with different disabilities, such as the needs of people who experience difficulty in understanding content or cues, people with limited memory or those who experience difficulty in perceiving visual information. Prior text accessibility heuristics frequently considered only the needs of people with dyslexia. As a methodological contribution to design science, we found that artefact evaluation should not only cover their means of effectiveness but also their feasibility. This means that the artefact solutions should also consider the possible influences of the context (being feasible) and the applier's needs and characteristics (being accessible itself). Involving the artefact's upcoming appliers in the development process can improve robustness because, in these cases, domain-specific concerns are already considered in the development process.

Article IV contributed to improving the natural use and effectiveness of the use of the heuristics presented in Article III. The original heuristics presented in Article III were assigned into three categories that objectively emerged from the literature. Therefore, the writing process was not addressed in the order of the heuristics. This paper aligned these heuristics to the cognitive process theory of writing (Flower & Hayes, 1981) and proposed an implementation model with a new sequential order of heuristics that is more consistent for use in the writing process. The implementation model improves the accessibility of the heuristics themselves because it fits the heuristics into the writing processes when the writer is about to organise and order the text and translate ideas into visible language. This makes them more natural and efficient to use during the writing process.

3.2 Practical Implications

The AM contributes knowledge to the ideal script of accessibility design. To improve information accessibility, computer output media should first be designed so that the information would be perceivable in the absence of sensory perception by the user of any variable in sensory perception. In addition, computer output modalities should be designed so that they also respond to variables of the user's cognitive ability. Similarly, computer input modalities should be designed to match variables in user functional operations. In addition, it is necessary for information to be formalised by considering the cognitive abilities of users to improve its quality. For example, written text content should be easy to understand.

Article II presented the factors that need to be addressed when designing accessible IT artefacts. Moreover, the study identified four domains that correspond to these factors: user, management, developers and IT artefact features. In addition, the study elucidated the roles of these domains and their relationships to other domains. These roles and relationships create interaction loops between the domains. In practice, this means that to create accessible IT artefacts, the interactions between users and IT artefact features, users and developers, management and developers, and developers and IT artefact features have certain activities that should be considered in IT development projects.

The study in Article III highlighted that content creators lack appropriate guidelines on how to produce and evaluate online text content accessibility. Existing guidelines are confusing, difficult to implement and too technical for the use of content creators. The need for the study is practical. Therefore, its implications contribute to practical work so content creators can apply the heuristics in their work when they are producing and evaluating text content for the web.

In Article IV, we improved the use of heuristics. We re-ordered them by comparing them with those of the cognitive process theory of writing by Flower and Hayes (1981) as it is a fundamental theory of human behaviour in a writing task. Thus, the results of this paper provide more effective premises for content creators to implement the heuristics.

3.3 Limitations, Objectivity and Trustworthiness

In this chapter, I present the limitations. Then, I discuss how objectivity and trustworthiness are built on prescriptive knowledge of accessibility. I present how this dissertation contributes to the objectivity and trustworthiness of accessibility research.

The construction of the AM in Article I was premised on selected theories from the literature. The articles presented samples on how accessibility can be described, relying on certain theories that have either been published in high-level IS or HCI journals or are well-known in practice. Furthermore, the AM is not a comprehensive instrument. Rather, it is an explanatory conceptual model that I hope will help researchers define and communicate their research focus more rigorously. The AM still requires empirical testing, so I cannot claim that the model is the best solution.

In Article II, we conducted a systematic literature review. We used the search term 'accessibility' solely, so studies that did not contain this particular term were excluded. We targeted research and empirical papers published in high-level journals in the IS and HCI disciplines. We conducted a search for the AIS 'basket of eight' journals, which were extended with a set of AIS-recommended high-level HCI journals and two-tier IS journals ranked by the Chartered Association of Business Schools. The search range may have created some biases because the database is restricted to certain journals, but we believe the selected 82 papers constituted a good sample and enabled us to achieve our research goals. In addition, the authors may have misinterpreted some studies in the data extraction phase. However, we made sure that every exclusion was conducted by at least two authors to ensure the reduction of biases.

In Article III, the prior studies examined consisted of research found via Google Scholar with a certain search term and string. We manually added the WCAG 2.1 and ICT4IAL guidelines to complement the heuristics selected as the starting point of the study. We believe our selected studies represented the state-of-the-art as they contained 10 separate sets of guidelines for web accessibility, including major guidelines such as the WCAG, Section 508 Web Standards and IBM web accessibility heuristics. Our proposed heuristics were designed for Western writing systems and are general in nature. The heuristics were not designed for any particular text genre.

In Article IV, we improved the sequential order of our heuristics presented in Article III in terms of their efficiency in the writing context. We relied solely on the cognitive process theory of writing (Flower & Hayes, 1981) when we aligned and compared the order of the heuristics to the writing process, which may have caused some biases. The proposed solution was not tested empirically.

Accessibility-related studies often base their definition of accessibility on standards such as ISO 9241–11:2018 or WCAG, which is also indexed in ISO standards. In practice, the legislation in the European Union (the Directive 2016/2102), for example, compels public digital services, websites and mobile applications to be accessible. Similarly, in the private sector, the European Accessibility Act requires all digital products established after June 2025 to be accessible (European Commission, 2015; European Telecommunications Standards Institute, 2015). These directives base their requirements on the WCAG. However, although ISO standards and WCAG are highly referred to and considered *de facto* in accessibility, accessibility scholars often claim that even after the full compliance of WCAG, websites remain unsatisfied and cover only around half of the accessibility problems that, for example, blind users encounter in the websites (Petrie et al., 2003; Vigo & Harper, 2013). Moreover, the literature also argues about the precise scope of accessibility and sometimes combines it with the concept of usability when a large amount of definitions leads to difficulties in the research community to interact and share understanding and knowledge of accessibility (Aizpurua et al., 2016; Petrie & Kheir, 2007; Santana & Baranauskas, 2015; Sauer et al., 2020; Yesilada et al., 2015). Therefore, it can be questioned how accessibility is understood. In practice, the law can easily be interpreted to mean that by complying with the requirements of the law, the product must be accessible. Notably, many researchers are interested in how their targets comply with accessibility requirements such as WCAG (c.f. Kamoun & Basel Almourad, 2014; Kuzma, 2010; Romano Jr, 2002; Yu & Parmanto, 2011). However, accessibility is more than just a law or compliance with the guidelines (Fagan & Fagan, 2004). This raises several ethical questions: *What is objectivity in the knowledge related to accessibility? What is the trustworthiness of accessibility research, and how can the results be justified and generalised for use to build IT artefacts for other contexts and tasks? Furthermore, how do these questions influence the conduct of accessibility research itself? Who is concerned with these ethical issues, and who is responsible for considering them?* The foregoing prove that despite advanced progress in awareness of accessibility, science still lacks a grand theory of accessibility, while practice lacks the knowledge on how to design IT artefacts that integrate accessibility solutions that respond to users with different abilities in a single solution (Meiselwitz et al., 2010). These deficits require us to first understand the scope of accessibility and then identify what the ability to use IT artefact means and how human-related processes are associated with it (this is addressed in Article I).

The large volume of literature, however, offers solid data that enable researchers to justify the trustworthiness of their studies, although the knowledge is fragmented. This is because of the empirical evidence that these studies have. For example, a study by Petrie and Kheir (2007) that involved blind and sighted participants revealed that accessibility problems are not a complete subset for usability problems, and usability problems are not a complete subset for accessibility problems. This means that having accessible content on a website does not make it automatically usable (Leuthold et al., 2008) and proves that accessibility and usability should be considered unique features. Furthermore, prior studies have provided a multitude of methods and techniques to include accessibility into the software process life cycle, including requirement elicitation, design, implementation, testing, maintenance, process establishment, training, measurement, process improvement, and most importantly, testing and design processes (Mack et al., 2021; Ordoñez et al., 2020; Paiva et al., 2021). Therefore, the objectivity of accessibility knowledge is evident in the sense that in the real world, it is obvious that features such as accessibility and usability are vital in facilitating people's interactions with IT artefacts. Therefore, these features should be provided equally for all. Research, laws and practice all have this same goal. However, there are different views with regards to the accuracy of how research measures these features (this is addressed in Article II).

When we attempt to design something for a certain use, and someone tries to apply it to some contexts, the factors that influence this whole process become more complicated. This dissertation identified three of these determinants: assumptions about users' abilities, users' actual needs and factors in the development chain. The assumptions about users' abilities (i.e. theoretical possibilities that users may lack among human abilities) are addressed in Article I. The importance of the inclusion of users' actual needs into the design is addressed in Article II. The factors in the development chain are addressed in Article II, and as a sample, Articles III and IV present accessibility guidance for content creation.

From the point of view of objectivity, scholars often suggest involving users in the design process by using participatory design, user-sensitive inclusive design or user-centred design (Gerling et al., 2016; Vollenwyder et al., 2019). Involving people with diverse needs and those with and without disabilities in the design process adds not only realistic perspectives regarding actual needs and challenges but also opportunities to identify new possibilities (Gerling et al., 2016; Seaborn et al., 2016). Users' participation and promotion of their needs are perceived as well-accepted methods in research and practice, which indicates that they can be justificatory to gain and present prescriptive knowledge (Article II).

In conclusion, some states of social objectivity can be identified from accessibility research. In fact, various groups of people are working to develop knowledge about the same question. The extensive research being conducted can represent the power of diversity in achieving accessibility for all users.

3.4 Future Research

In this chapter, I present the future directions for accessibility research that emerged and were identified during the research process in Articles I–IV, as well as the contributions of this dissertation.

The aim of this dissertation was to provide theoretical knowledge of how users interact with IT artefacts, theoretical knowledge of what factors are essential to consider in the IT development process and prescriptive knowledge on accessible text content production. The synthesis raised three determinants of knowledge of accessibility that are essential for prescriptive knowledge that would help practitioners create accessible IT artefacts in their desired tasks and contexts. However, this dissertation is not comprehensive. I believe we are still quite far from the situation where people can use digital services without any problems. Furthermore, we are constantly encountering new technological artefacts, which makes accessibility design an endless process. These identified determinants require more research and can be considered as a future research stream.

Whatever future technology will arise, the assumptions about users' abilities to use IT artefacts should be considered. This dissertation calls for empirical studies to investigate the practical feasibility of the determinants of knowledge of accessibility in the design theory-building process. The theoretical contributions of Article I are explanations of the components of accessibility and how these are related to one another in HCI. Article II presents the principles of what kind of IT artefact should be created. This calls for research to investigate how the design solutions for a target audience influence others. Do the solutions that benefit some target groups always benefit other target groups? Are there any contradictions? This calls for research on how to design IT artefacts in practice: How should computer output media be formalised to match users' varying abilities in sensory perception? How should computer input modalities be designed to match users' varying functional operation channels? How should information be expressed through computer output media so that users with varying cognitive abilities will be able to understand and use it?

Poor IT accessibility has driven people to design assistive technology for users who cannot operate these IT artefacts. Thus, assistive technology has become a factor with which compatibility with the IT artefact should be considered in the design. Assistive technology (AT), such as screen readers, is often discussed in accessibility research as it augments access and benefits many users. The use of AT is vital to some, but for others, the use and acceptance of an AT depend on how users perceive social acceptance. The perception of social acceptance may have an influence on their decision to apply these technologies. Therefore, the question of how social acceptance influences AT acceptance should be posed.

The future development chains, as well as current ones, can be extremely diverse. Therefore, the factors in the development chain require more research. One of the key factors that emerged from the studies was the theme of motivation to promote accessibility. I identified motivation as a factor that exerts influence on several levels. For example, businesses, as well as research and interest groups, may have different motivations (Neufeldt et al., 2007). Managers, developers and users have different characteristics and motivational factors (Lazar et al., 2004; Vollenwyder et al., 2019). The knowledge of accessibility and user participation is seen to improve developers' motivation to promote accessibility (Gerling et al., 2016; Jaeger, 2006). In Article III, the participants reported the requirements for the presentation and layout of the heuristics. They suggested features for the layout (e.g. icons, colours and mnemonics) to improve their learning, memorability and motivation to use the heuristics. This calls for more research to investigate what factors motivate practitioners to promote accessibility. This can be addressed in higher education as a societal foundation (Lazar et al., 2004), particularly in the IS discipline, which has the responsibility of educating future IT practitioners about accessibility.

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Original Articles

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II. Mäkipää, J.-P., Norrgård, J., & Vartiainen, T. (2022). Factors Affecting Accessibility of IT Artifacts: A Systematic Review. *Communications of the Association for Information Systems.* (forthcoming), In Press.

III. Mäkipää, J.-P., & Isohella, S. (2022). Designing Heuristics for Accessible Online Text Production. *Scandinavian Journal of Information Systems*, 34(1), 165–198. https://aisel.aisnet.org/sjis/vol34/iss1/5

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Explaining Accessibility: Possible Variables in Users' Abilities, Tasks and Contexts in IT Artefact Use

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Abstract

The interconnection between two information technology (IT) artefact qualities, namely, accessibility and usability, is challenging to define. The design and development of accessible IT artefacts should encompass the broadest range of user abilities in identified tasks and contexts. Research on information systems and human–computer interactions is limited, with the literature presenting a complex model that explains what variables these key components of accessibility contain and how they are interconnected. To address this gap in the literature, I draw upon theories beyond human–computer interactions, tasks and contexts to posit the influence of human abilities on IT use by referring to the taxonomies of the International Classification of Functional Abilities by the World Health Organization. This article develops a theoretical description of accessibility, its components and their relationships in the IT use context. As a result, an Accessibility Model is presented. Furthermore, it is argued that accessibility is a moderating variable[1] between system features and usability. Therefore, accessibility is a major determinant of user acceptance.

Keywords: accessibility theory, user abilities, IT artefact

[1] The term moderating variable in this study refers to a variable that can strengthen, weaken, change the direction or otherwise affect the relationship between independent and dependent variables (Allen, 2017).

1 INTRODUCTION

The code of ethics of two major scientific societies, namely, the Association for Information Systems (AIS) and the Association for Computing Machinery (ACM), states: 'Technologies and practices should be as inclusive and as accessible as possible, and scholars and computing professionals should take action to avoid creating systems or technologies that disenfranchise or oppress people' (Association for Computing Machinery, 2021; Association for Information Systems, 2021; Hanson, 2017). The majority of accessibility-related studies and approaches describe accessibility as an extent. For example, studies often refer to the well-known International Organization for Standardization (ISO) Standard 9241-171:2008, which defines accessibility as the 'extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use' (ISO, 2018). A large body of studies has explained the relationship between human cognition and technology (Germonprez et al., 2007). Schomaker and Hartung (1995) described the interaction process between humans and computers, while Gerlach and Kuo (1991) and Norman (1986) elucidated the user task performance behaviours in human-computer interaction (HCI). However, describing and explaining the possible variables in users' abilities, tasks and contexts in the HCI process are challenging when the majority of these descriptions remain holistic and, thus, vague. The vague description of accessibility has led to scholars constantly arguing about the difference and overlap between accessibility and usability and whether the definition of accessibility should include usability or not (Aizpurua et al., 2016; Petrie & Kheir, 2007; Santana & Baranauskas, 2015; Sauer et al., 2020; Yesilada et al., 2015). This has given rise to problems because the amount of definitions and perspectives for 'accessibility' has made it difficult for members of the community to interact or gain understanding and knowledge (Yesilada et al., 2015). Practice indicates that the interconnection between accessibility and usability significantly overlaps. Accessibility is primarily focused on people with disabilities, while usability is concerned with overall improvement (WAI, 2021). For researchers, the ambiguity of this interconnection may affect their ability to discriminate between the features of the two concepts during evaluation (Aizpurua et al., 2016).

Because of the complex nature of human abilities, detailed theoretical descriptions of the components of accessibility and its interplay with usability are needed to narrow down the target of the research more accurately (Santana & Baranauskas, 2015). As a response to this problem, the aim of this article is to contribute a richer theory that explains the variables in users' abilities and IT artefact use contexts and tasks. In addition, it aims to show what factors influence users' access to information. Therefore, the following research questions (RQ) are posed:

RQ1: What is the scope of accessibility, and how is it interconnected to usability?

RQ2: What are the possible variables in the components of accessibility, and how are they related to each other?

In this article, I 'disassemble' the definition of accessibility (ISO 9241-171:2008) into three main components influencing product (IT artefact) use: 1) human abilities; 2) identified goals (i.e. user tasks); and 3) context of use (c.f. International Organization for Standardization, 2018; Petrie et al., 2015). Then, I review the kernel theories related to these components, their constructs and statements of relationships to address the research questions. I synthesise and 'reassemble' four theoretical streams to develop the description of accessibility: 1) theories of human abilities; 2) task theories; 3) theories describing the context of use; and 4) theories of human–computer interaction. I use the 'structural components of theory' by Gregor (2006) as a lens to extract possible components of theory, constructs, statements of relationships and scope. However, the performed review is not systematic or comprehensive in nature. First, the proposed Accessibility Model (AM) draws upon the theories of human abilities: the International Classification of Functioning, Disability and Health (ICF) agreed upon by the World Health Assembly in 2001 (World Health Organization [WHO], 2013) and Cattell-Horn-Carroll's (CHC) theory of intelligence within cognitive abilities (McGrew, 2009). Second, it draws upon the well-known theory of task performance by Norman (1986). Third, it draws upon theories describing the context of use (McKay et al., 2012). Finally, as a starting point for theory development, it draws upon the theory of human behaviour with a computer: the basic model of human–computer interaction by Schomaker and Hartung (1995).

This is a theory development paper that takes a step toward providing a more detailed description of accessibility. It does not attempt to redefine the concept of accessibility or its desired extent but to explain the 'anatomy of accessibility', thereby helping researchers 1) recognise the relationship between the components in the concept of accessibility; 2) define and align their intended research focus—related to human ability—with a clear picture of accessibility for them to see the related factors; and 3) gain an understanding of the variables in human abilities related to interactions with IT and the varieties in task characteristics and context of use that both affect the interaction. According to Weick (1995), a list of the variables does not represent a well-developed theory but can still convey a message of the relationship and causation of the items. Therefore, this study will not only list variables but also describe the relationship between the constructs.

The rest of this paper is structured as follows. The next section addresses RQ1 by presenting prior descriptions of accessibility and its interconnections to usability. Then, theories of the components of accessibility are described as prior knowledge for RQ2. Then, a synthesis of this knowledge and the relationships of the components are illustrated in the AM. Then, I demonstrate the use of the AM by juxtaposing it to well-known technology acceptance models (TAMs) and discussing the relationship to usability. Finally, I evaluate the AM by comparing it to other models describing accessibility.

2 DEFINITIONS AND GENERAL DISCUSSION OF ACCESSIBILITY

The purpose of this section is to present prior knowledge for the question *What is the scope of accessibility and how is it interconnected to usability?* First, the section will briefly present the focal definitions and prior conceptualisations of the theory of accessibility and usability, as well as the related concepts of universality in current literature and practice. Next, the section demonstrates how the literature presents varying definitions of accessibility and usability, allocating a lesser focus to describing the construct of accessibility.

2.1 Definitions and Explanations of Accessibility and Related Concepts

Persson et al. (2014) derived various accessibility-related approaches, such as barrier-free design, design for all, universal design, inclusive design, accessible design, universal access and cooperative design. They also considered accessibility legislation and standards to combine the goals and defined accessibility as 'the extent to which products, systems, services, environments and facilities are able to be used by a population with the widest range of characteristics and capabilities (e.g. physical, cognitive, financial, social and cultural, etc.) to achieve a specified goal in a specified context'. A convention of the United Nations (2006) considered accessibility as a human right, stating that parties should promote the design, development, production and distribution of information accessibility at the early stage of information and communication technology (ICT) designing processes and aim to produce IT artefacts (e.g. websites) that are accessible for the broadest range of users to address their various needs.

As for usability, ISO 9241-11:2018 defines usability as the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. According to these definitions, usability entails measurable goals (effectiveness, efficiency and satisfaction) that can be used to design or evaluate a system's usability quality. By contrast, the definition of accessibility only indicates the state of use (is accessible or has accessibility issues). Moreover, this definition explicitly states '*specified users*', which leaves the decision to target a certain group of people. One of the most cited theories of usability is Nielsen's usability definition as part of acceptability (Google Scholar: 23068 citations, 2021), which posits usability as one of the key factors of usefulness towards acceptability (Nielsen, 1993). Nielsen (1993) divided usability into five attributes that provide usefulness: easy to learn, efficient to use, easy to remember, contains few errors and be subjectively pleasant.

If we combine the desired extents of accessibility and usability as described in ISO standards, it becomes the ideal extent of IT use, where users, regardless of their capabilities, disabilities, impairments, or disabling conditions, perceive use as effective, efficient and satisfying with or without assistive technology (AT). In practice, this means that both accessibility and usability need to be successfully incorporated into IT artefacts (Aizpurua et al., 2016). The extent to which usability appeals to all users during any task in any context is called 'universal usability' (Aberg & Shahmehri, 2001; Henry et al., 2014; Petrie & Kheir, 2007; Shneiderman, 2000). In addition, Meiselwitz et al. (2010) included varieties in technological diversity (hardware, software and network), user diversity (impairments, learning disabilities, low literacy level, age, gender, socio-economic status, cultures, etc.) and context (environmental factors, such as location, time, device type, and the user's current cognitive or psychological state) in universal usability. However, in discussions about universal usability, Henry et al. (2014) recommended keeping the focus of accessibility on user diversities rather than issues of situational limitations caused by context because there is significant overlap in design strategies and solutions for people with disabilities and those with situational limitations. Before universal usability can be reached, a successfully completed state of use needs to be reached (Davis et al., 1989; McKay et al., 2012). Concepts under the domain of universal accessibility attempt to cover all diversities in users' abilities in various contexts (Obrenovic et al., 2007; Savidis & Stephanidis, 2004). In this article, issues such as availability of suitable technology, financial means to ensure access to ICT for all people, education, ICT literacy and skills, culture, age and language are excluded from universal accessibility because they are more often related to the concepts of inclusion or digital division (Abascal et al., 2016; WAI, 2021).

Overall, accessibility can be perceived as a complex concept (Persson et al., 2014) that can be divided into three layers: 1) computer accessibility (interaction and access between software and hardware); 2) browser accessibility (browser features and user agents, AT and web navigation technology); and 3) web accessibility (web content and structure that users perceive and interact with) (Sevilla et al., 2007). Meanwhile, Culnan (1984) divided accessibility into physical accessibility of system use, where devices are physically available to the user, and information accessibility, which includes three dimensions: 1) physical (use of a computer); 2) interface (a user's interaction with 'non-natural language'); and 3) informational (a user's ability to retrieve information independently). According to Culnan (1984) and from further investigations by Loiacono et al. (2013), information accessibility can be divided into three dimensions influencing users' intention to use the system: 1) perceived convenience (users perceive access to the information as convenient, which influences their intention to use the system and their perception of ease of use); 2) perceived reliability, (users see the system providing access that is reliable, dependable and failure-free; perceived reliability influences users' intention to use, perception of ease of use, and perception of usefulness); and 3) perceived ease of use, (users perceive the system as user-friendly, flexible and forgiving). Notably, information accessibility has a significant impact on perceived usefulness and perceived ease of use in the users' acceptance process (Djamasbi & Tullis, 2006; Loiacono et al., 2013).

An accessible IT artefact also allows AT, such as screen readers, screen magnifiers, voice recognition, alternative devices and displays to be used to access elements of the system to ensure equitable access for people with disabilities. (Babu et al., 2010; Lazar et al., 2004; Petrie et al., 2015). AT renders content decoding to multi-modal channels (visual, auditory, tactile), which facilitates users' interaction with information (Watanabe, 2017). However, due to AT, potential accessibility barriers become even more complex to understand (Vollenwyder et al., 2019). To attain access for all, for example, in the European Union, Directive 2016/2102 is compelling public digital services, websites and mobile applications to be accessible. Similarly, in the private sector, the European Accessibility Act requires all digital products established after June 2025 to be accessible (Directive 2016/2102 (2016) of the European Parliament and of the Council of 26 October 2016, 2016; European Telecommunications Standards Institute, 2015). These directives require compliance with the middle-level of the Web Content Accessibility Guidelines (WCAG) provided by a group of Web Accessibility Initiative (WAI) from the World Wide Web Consortium (W3C). However, although ISO standards and the WCAG are highly cited and considered *de facto* in accessibility, scholars often claim that even full compliance with these standards and guidelines does not guarantee good accessibility or usability when websites remain unsatisfying (Aizpurua et al., 2015; Babu et al., 2010; Berget et al., 2016; Lazar et al., 2004; Leuthold et al., 2008; Martins et al., 2017; Vollenwyder et al., 2019). For example, regarding the accessibility problems encountered by blind people, only around half are covered by WCAG (Aizpurua et al., 2015, 2016; Giraud et al., 2018; Petrie et al., 2003).

To gain an understanding of how people interact in accessing information, accessibility scholars often investigate certain target populations and their needs for a successful interaction. For example, Martins et al. (2017) recommended defining a specific scope, such as using accessibility guidelines or characterising the target population with attention to the users' capability limitations and other attributes when evaluating accessibility.

2.2 Discussions Between Accessibility and Usability

Some prior studies emphasise the importance of usability's inclusion in the concept of accessibility. According to Link et al. (2006), accessible IT artefact should be perceived as easy to learn and easy to use. Similarly, Cairns et al. (2019) argued that accessibility in user interface (UI) interactions is no longer a question of whether people can perceive and operate the UI. Thus, IT artefacts should provide usability to as many people as possible regardless of their ability (Giraud et al., 2018; Leuthold et al., 2008; Link et al., 2006; Martins et al., 2017; Ruiz et al., 2011; Vollenwyder et al., 2019). However, an analysis by Petrie et al. (2015) of 50 definitions of web accessibility in books, papers, standards, guidelines and online sources reveals that only 30% mentioned usability. Moreover, Yesilada et al. (2015) confirmed that the web accessibility community thinks that accessibility and usability are only highly related.

Petrie et al. (2015) presented a unified definition of web accessibility, including usability, as follows: 'All people, particularly disabled and older people, can use websites in a range of contexts of use, including mainstream and ATs; to achieve this, websites need to be designed and developed to support usability across these contexts'. In this case, accessibility is perceived as a necessary precondition for usability, and only after a successful interaction with IT artefacts can other qualities such as usability and user experience (UX) be positively gained (Cairns et al., 2019; Davis et al., 1989; Iwarsson & Ståhl, 2003; McKay et al., 2012; Meiselwitz et al., 2010). However, a study by Petrie and Kheir (2007) with blind and sighted participants revealed that accessibility problems are not a complete subset for usability problems, and usability problems are not a complete subset for accessibility problems. This means that accessible contents on websites do not make them automatically usable (Leuthold et al., 2008). For example, according to Leuthold et al. (2008), WCAG does not bring a significant difference in efficiency, errors or satisfaction in website usage among blind users. Hence, once accessibility has been achieved, the interaction design should provide good usability, meaning that people with disabilities should be able to exploit the interface equally, efficiently, effectively and safely; they should perceive the interaction to be a satisfying and good experience with a reasonable amount of time and effort (Cairns et al., 2019; Giraud et al., 2018; Leuthold et al., 2008; Little et al., 2005; Santana & Baranauskas, 2015). Similarly, Aizpurua et al. (2016), Giraud et al. (2018) and Santana and Baranauskas (2015) stated that accessibility and usability play a significant role in attaining a successful system, so these elements should be considered and addressed together. According to Aizpurua et al. (2016), accessibility also correlates with 27 of 35 UX attributes, mostly with hedonic UX qualities. Therefore, deep focus and appropriate considerations of accessibility are crucial. Otherwise, IT artefacts would exclude a significant group of potential users whose ICT use relies on appropriately provided accessibility (Aizpurua et al., 2016). In addition, according to a study by Yesilada et al. (2015), accessibility is applicable to everyone and not just to people with disabilities.

Although accessibility and usability have been difficult to define with clear distinctions between their qualities, it is evident that accessibility and usability need to be integrated properly; otherwise, websites, for example, would be inaccessible but usable or accessible but not usable (Aizpurua et al., 2016). Moreover, they can become useless for people with disabilities and would lack usability for all (Santana & Baranauskas, 2015).

In summary, despite the variation in definitions, there is a consensus in prior accessibility research that making accessibility improvements, like using universal design principles for a website, makes them more effective (Djamasbi & Tullis, 2006). Past studies on accessibility have formulated theories of accessibility by often referring to the desired extent stated in focal accessibility definitions, such as in ISO standards.

Although the consequences of confusing accessibility and usability are a cause for concern, studies that attempt to describe the relationship between accessibility and usability build their models on a holistic picture of interaction, where the difference between these qualities remains vague. For example, Sauer et al. (2020) examined the meaning of the concepts of accessibility, usability and UX and their relationship with one another. They proposed a new higher-level concept called 'interaction experience' as an umbrella term for a more holistic view of the experience gained in interactions with IT artefacts. Obrenovic et al. (2007) described the fundamental connection between universal accessibility and multi-modal interface design. They presented a framework to identify whether the design of the interface is appropriate for a particular situation and how one interaction modality affects users' abilities. For example, hand movements during an interaction require users' motor, perceptual and cognitive abilities (Obrenovic et al., 2007).

The overall findings of these studies offer a good starting point to frame the components of an accessible IT artefact to construct a descriptive explanation of the user process of accessing information.

3 OVERVIEW OF THEORIES: THE COMPONENTS OF ACCESSIBILITY

To address the question, *What are the possible variables in the components of accessibility?*, the following section draws upon the basic theories related to each component of accessibility. These focal components are retrieved from the definition of accessibility in ISO 9241-171:2008, which is simplified as follows. ***People with various abilities*** can ***interact*** with ***IT artefact features*** to use the ***information*** for an identified ***task*** in the identified ***context of use*** (International Organization for Standardization, 2018; Persson et al., 2014; Petrie et al., 2015). The extracted focal components are seen as constructs of 'accessibility'. They are *user abilities, interactions, product features, tasks* and *contexts of use*. Technological components such as a computer (interaction between software and hardware), browser features, user agents and AT are scoped out because these components influence the interaction, and this study attempted to describe only the interactions between users and IT artefacts.

Table 1. Summary of the Components of Accessibility

Component	Theories Reviewed	Summary of the Possible Variables	References
User abilities	International Classification of Functioning, Disability and Health (ICF); Cattell–Horn–Carroll's (CHC) theory of intelligence	User sensory perception, cognition and human functional operation	Berget et al., 2016; Carroll, 1993; Lee & Nass, 2003; McGrew, 2009; Nass et al., 1994; Sevilla et al., 2007; WHO, 2002, 2013, 2021

Interaction (the use of computers)	Basic process of human–computer interaction (Schomaker & Hartung, 1995)	User perception, cognition and action (human input and output channels) Computer output media and computer input modalities	Babu et al., 2010; Gerlach & Kuo, 1991; McGrew, 2009; McKay et al., 2012; Schomaker & Hartung, 1995
Product features	The model of user experience (Hassenzahl, 2003); WCAG	Content, presentation style, functionality, interaction style and structure	Hassenzahl, 2003; W3C, 2018
Task	Seven stages of action (Norman, 1986)	Task characteristics, user's mental and physical activities: establishing the goal; forming the intention; specifying the action sequence; executing the action; perceiving the system stage; interpreting the state; and evaluating the system state with respect to the goals and intentions	Carroll, 1993; Gerlach & Kuo, 1991; Norman, 1986
Context of use	Universal usability (Shneiderman, 2000); Socio-Technical Model (Lyytinen & Newman, 2008)	Environmental factors, socio-cultural factors, cultural, political and sociological factors, history of that context, context of IS, socio-technical components	Lyytinen & Newman, 2008; McKay et al., 2012; Meiselwitz et al., 2010; Sharp et al., 2020; Shneiderman, 2000; WHO, 2013

3.1 User Abilities

To classify a person's functional abilities in this article, I used the ICF, which was agreed upon by the World Health Assembly in 2001 (WHO, 2002). Despite its potential, the ICF is still rarely used in IS or HCI studies. ICF is commonly used by disability experts in governments and other sectors (WHO, 2013). Cinquin et al. (2019) recommended that system or feature design should consider ICF, for example, in learning activities. To understand and follow the large scale of human psychological and physical differences, the ICF framework is utilised in identifying human factors. The ICF framework presents possible disabilities in a person's interactions with the social, physical and digital environments (Cinquin et al., 2019). The ICF is a tool to measure functioning in a society with a focus on health, functioning and a person's abilities, rather than disabilities that may risk separating people into different categories (WHO, 2002). Thus, the ICF helps understand human diversities and collects knowledge of the basic needs of individuals based on impairments or complex disorders (WHO, 2013).

The ICF proposes two conceptual models of disability. First, the medical model defines disability as a feature of the person caused by disease, trauma or other health conditions requiring medical treatment to 'heal' the individual (WHO, 2013). Second, the social model sees disability as a socially created problem in which an unaccommodating environment is created by neglecting the rights of persons with disabilities (WHO, 2013).

Finally, the ICF provides an intergraded model of disability that considers both the medical and social models, including biological, psychological and social perspectives. This more familiar biopsychosocial model of disability is organised into two parts: 1) functioning and disability, which includes body functions and structures, as well as activities and participation; and 2) contextual factors, including environmental factors and personal factors (WHO, 2021; WHO, 2013). In this article, the ICF is adopted, and only the factors related to human–computer interactions, such as user sensory perceptions, cognition and functional operations, are retrieved.

3.1.1 User Sensory Perception

The ICF classifies human sensory functions as follows: seeing and related functions, hearing and vestibular functions, taste function, smell function, proprioceptive function, touch function, sensory functions related to temperature and other stimuli, and pain (WHO, 2002) (see Appendix 1 for Body Functions – Sensory Functions and Pain).

3.1.2 Cognition

Cognitive ability and possible patterns of cognitive deficits are different for each individual (Berget et al., 2016; Sevilla et al., 2007). Therefore, when analysing issues relating to cognitive deficits, it is necessary to consider each specific cognitive deficit rather than considering cognitive matters as a whole (Sevilla et al., 2007). According to the CHC theory of intelligence, the interpretation and organisation of perceived data constitute a cognitive process that involves cognitive abilities such as reasoning, comprehension, short-term and long-term memory, reading and writing, and visual and auditory processing, which refer to the ability to generate, store and retrieve visual information and analyse, manipulate and comprehend auditory information (McGrew, 2009). Carroll (1993) defined ability as an attribute of an individual that refers to the possible variations in the liminal levels of task difficulty (or in derived measurements based on such liminal levels) at which, on any given occasion where all conditions appear favourable, individuals successfully perform a defined class of tasks. ICF does not provide a definitive list of human cognitive deficits but describes the functions of the brain as mental functions, such as attention functions, memory functions, thought functions, mental functions of language, calculation functions, psychomotor functions, a mental function of sequencing complex movements, emotional functions, higher-level cognitive functions, and experience of self and time functions (see Appendix 1 for Specific Mental Functions). Moreover, ICF provides the following abilities for applying knowledge: focusing attention, thinking, reading and writing, calculating, problem-solving, and making decisions (see Appendix 2 for Applying Knowledge) (WHO, 2021).

To conclude, the awareness of individuals' cognitive abilities to perform tasks and the adoption of this knowledge into the design of IT artefacts are crucial for creating a successful interaction.

3.1.3 Human Functional Operations

Human outputs or actions in IT use, such as typing with a keyboard and using pointing devices, touch screens and others, require at least one human functional ability (Carroll, 1993). ICF classifies human functional abilities as follows: voice and speech functions (voice functions, articulation functions, fluency and rhythm of speech functions, alternative vocalisation functions) and neuromusculoskeletal and movement-related functions (functions of the joint and bones, muscle functions, movement functions) (see Appendix 1) (WHO, 2021). As human–computer interactions can also be considered social interactions (Lee & Nass, 2003; Nass et al., 1994), human abilities for social interaction, such as abilities for interpersonal interactions, relationships and communication (receiving and producing, conversation, and use of communication devices and techniques) (WHO, 2021), can affect social interactions in a digital environment. Therefore, they should be considered in designing for accessibility. ICF divides the abilities for interpersonal interactions and relationships into abilities for basic and complex interpersonal interactions, relating with strangers, formal relationships and informal relationships (see Appendix 2) (WHO, 2021).

3.2 Interaction

Human interaction with an IT artefact involves a user's three basic processes: perception, interpretation (i.e. cognition) and action (Babu et al., 2010; Gerlach & Kuo, 1991; McKay et al., 2012). The communication between humans and IT artefacts starts with the user's perception and continues to the interpretation of perceived data (Gerlach & Kuo, 1991). Human perception receives information generated through the body positions and senses, such as sight, hearing and touch. Humans have varying abilities to perceive data. Once the user has perceived the data, the interpretation process starts. Schomaker and Hartung (1995) described human–computer interaction as having two actors: the human and the computer. Both actors receive outputs and send inputs to each other. The computer output is an input for humans. Human output is an input for computers. The exchange between these actions is called the interaction. Within one actor, there is a process between received input and sent output. In the human actor, this process is called cognition (i.e. the human mental process involved in gaining knowledge and comprehension) (McGrew, 2009). In the computer, 'cognition' refers to computer data processing.

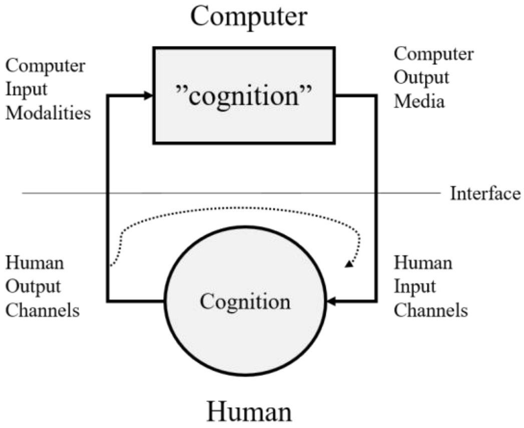

Figure 1. Basic Process of Human-Computer Interaction (Schomaker & Hartung, 1995)

3.3 Product Features

As the term 'IT artefact' may have different meanings, in this article, IT artefact is defined as an application (e.g. web application, website, UI…) or a component of IS that enables or supports some tasks embedded within the structure in some context (Alter, 2008; McKay et al., 2012). IT artefacts have certain features, such as content, presentation style, functionality, interaction style, and structure whereby users interact to use information (Hassenzahl, 2003; W3C, 2018). According to Hassenzahl (2003), individuals construct their own conceptual version of the artefact's character based on personal judgment (emotional consequences such as pleasure, satisfaction, etc. and behavioural consequences such as increased time spent with the artefact). Notably, regardless of the design process or method, only one design solution of an IT artefact is realised after the construction process (McKay et al., 2012).

3.4 Tasks

User tasks refer to the processes whereby the user has to do or should be able to do some tasks (Savidis & Stephanidis, 2004). The performance of any task usually requires more than one ability. For example, a simple task that asks the user to select 'Yes' or 'No' in response to a presented question requires the ability to see, recognise and read the words; to understand the meaning of the words; to evaluate the oppositeness of the answers and understand the consequences; and, finally, the ability to make a selection physically with the device (Carroll, 1993). Norman (1986) described a user's mental and physical activities in the process of performing a task using seven stages: 1) *establishing the goal*; 2) *forming the intention*; 3) *specifying the action sequence*; 4) *executing the action*; 5) *perceiving the system stage*; 6) *interpreting the state*; and 7) *evaluating the system state with respect to the goals and intentions*. Therefore, task performance requires cognitive and physical activities from a user. Gerlach and Kuo (1991) suggested that an HCI design includes various elements. The first is the conceptual aspect, such as task analysis and design. The second is the physical aspect, such as the design of action and style of presentation that enables the user to communicate with the system to be considered. Task design and division of complex tasks into smaller, precisely defined tasks have a positive effect on motivation and engagement (Jackson et al., 2015; Sprinks et al., 2017; Tinati et al., 2017), which can be strengthened, for example, with gamification and game elements (Prestopnik et al., 2017; Tinati et al., 2017; Zhou et al., 2017).

3.5 Context of Use

The ISO standard states that the design should be addressed to the 'identified context of use'. However, identifying the scope of the context of use may be challenging. According to Meiselwitz et al. (2010) and the WHO (2013), the design for a context should meet environmental factors such as location, time, type of device in use and the current emotional state (cognitive or psychological state) of the user. In addition, Sharp et al. (2020) stated that socio-cultural factors, such as customs, traditions and beliefs that drive users' thoughts, feelings and behaviours are essential to understanding genuine problems. Moreover, McKay et al. (2012) described the context of use to be composed of the properties of the interactions among technical, human and organisational elements, whereby the cultural, political, sociological and historical aspects of the context influence users. The actual computer use context includes perception, interpretation and use (McKay et al., 2012). McKay et al. (2012) suggested having a socio-technical viewpoint that includes human-centred design knowledge and construction-centred design knowledge for designing artefacts for the context of use to meet the requirements of both approval and use. If we consider IT artefacts as components of IS artefacts (McKay et al., 2012), the context of IS needs to be understood. The Socio-Technical Model by Lyytinen and Newman (2008) helps identify possible imbalances or gaps as critical incidents between the following socio-technical components: actors, technology, task or structure. Therefore, in the context of use in a socio-technical system, a user may face problems in operating, understanding or accepting tasks, structures or technology, which can be realised in three simple conditions: the user 1) *does not understand*, (2) *cannot operate* or (3) *does not accept* the tasks, structure or technology (Lyytinen & Newman, 2008). Moreover, individual characteristics and abilities, task characteristics, external environment and supporting systems influence these conditions (Bostrom & Heinen, 1977).

4 SYNTHESISING KNOWLEDGE OF THE ACCESSIBILITY COMPONENTS INTO A MODEL

The AM, which is a result of the synthesis of prior theories related to the components of accessibility, is illustrated in Figure 2. The AM explains the construct of 'accessibility', including the components, variables, processes and their relationships. The AM is intended for IS and HCI researchers to align their identified research problem with the picture of accessibility to see their relationship and the possible related variables to increase the rigorousness of accessibility-related research.

Figure 2 presents a conceptual case whereby a user interacts with IT features to access and use information (see the explanations in Table 2). The first column in Table 2 includes the components of accessibility stated in the simplified definition. The second column includes the possible variables of each component listed, as well as processes (if any).

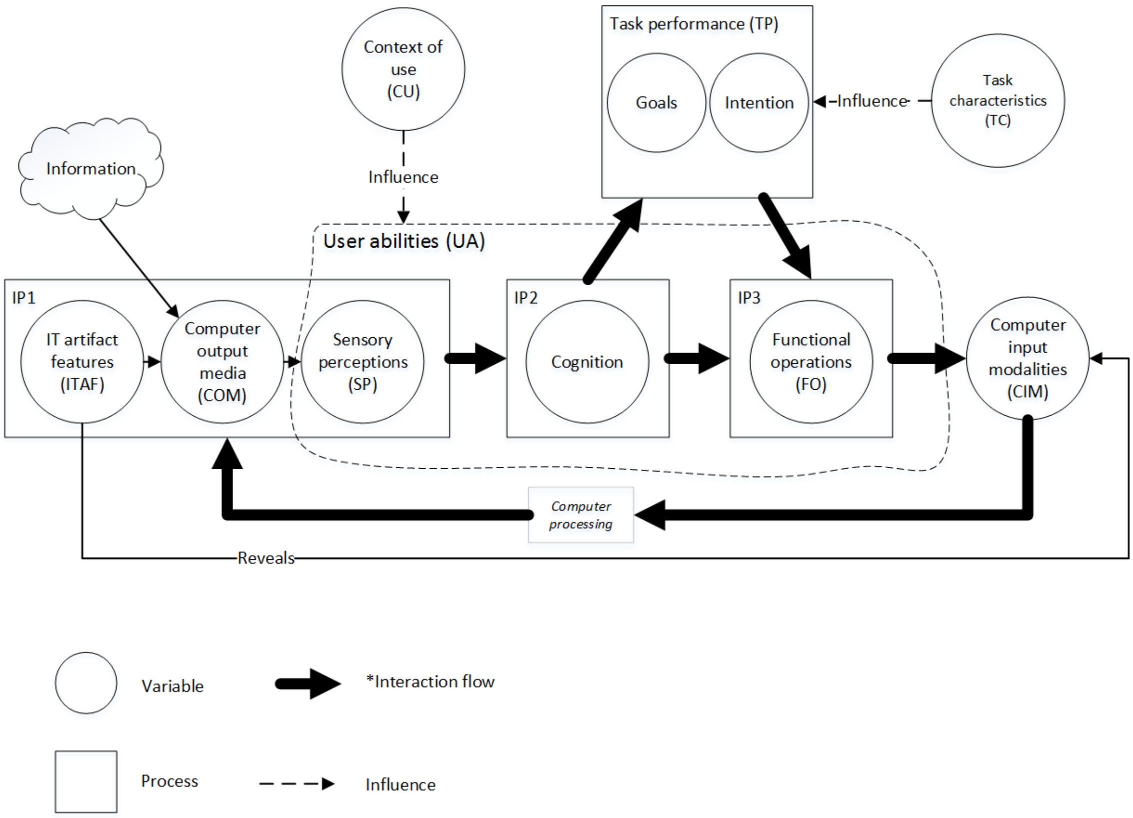

Figure 2. Accessibility Model (AM)

*In the AM, the interaction flow illustrates the cycle of information exchange between the user and the computer. It should rotate as long as the user reaches the information. If this rotation ends or is interrupted by a mismatch between the UA and COM or CIM, the ITAF or the information becomes inaccessible.

Table 2. Explanations of Variables and Relationships Between the Components of Accessibility

Components	Variables and Processes	References
Users with various abilities can	Users' abilities (UA) vary in terms of: (1) Sensory perceptions (SP) – *sight, hearing, touch, smell, taste and balance;* (2) Cognition - *focusing attention, memory, thinking and speed of processing, reading and writing, mental functions of language, calculating and quantitative knowledge, solving problems, making decisions and reaction speed, psychomotor functions and sequencing complex movements and speed, emotional functions, perceptual functions, higher-level cognitive functions and domain-specific knowledge, experience of self and time functions, comprehension-knowledge; and* (3) Functional operations (FO) – *movements, voice, and sight.*	Berget et al., 2016; Carroll, 1993; McGrew, 2009; Schomaker & Hartung, 1995; Sevilla et al., 2007; WHO, 2021, 2013
Interact with	The interaction process (IP) includes the following UA: (IP1) = SP receives ITAF via COM and transmits information to IP2; (IP2) = Cognition interprets and organises perceived data from IP1 and guides IP3; and (IP3) = Receives information from IP2 and directs FO for actions with computer input modalities (CIM) (*movements, force, sound, images)* revealed by IT artefact features (ITAF).	Babu et al., 2010; Gerlach & Kuo, 1991; McKay et al., 2012; Schomaker & Hartung, 1995
IT artefact features to use	IT artefact features (ITAF) include: *content, presentation style, functionality, interaction style* and *structure.* These features are revealed through computer output media (COM): *visual, auditory, tactile, olfactory, gustatory or vestibular.*	Hassenzahl, 2003; Sevilla et al., 2007; W3C, 2018
Information identified	Information is a conceptual component presented with some of the COM modalities.	Culnan, 1984; Djamasbi & Tullis, 2006; Loiacono et al., 2013; Schomaker & Hartung, 1995; W3C, 2018
Task identified	Task performance (TP) includes the following IP: the user evaluates the results of IP1 and IP2 with respect to *goals* and *intentions*, whereupon the user proceeds to IP3. Task characteristics (TC), such as *complex, motivating and engaging,* influence TP.	Carroll, 1993; Jackson et al., 2015; Norman, 1986; Prestopnik et al., 2017; Sprinks et al., 2017; Tinati et al., 2017; Zhou et al., 2017
Context of use	Context of use (CU) varies in terms of *environmental factors, users' emotional state, socio-cultural factors and socio-technical factors wherein the cultural, political, sociological and historical aspects of that context influence the user, among others.*	Lyytinen & Newman, 2008; McKay et al., 2012; Meiselwitz et al., 2010; Sharp et al., 2020; WHO, 2013
Texts in *italics* indicate possible variables.		

The components and their variables presented in Table 2 are described in detail. The abbreviations of the components, variables or processes are shown in Figure 2.

The range of ***user abilities*** (UA) varies. Similarly, users' sensory perceptions (SP) differ in terms of abilities in *sight, hearing, touch, smell, taste and balance* (Schomaker &

Hartung, 1995; WHO, 2021; WHO, 2013). The domains of users' cognitive abilities can be classified and unified based on the CHC theory by McGrew (2009) and the ICF classification of human ability to apply knowledge as follows: focusing attention, memory, thinking and speed of processing, reading and writing, mental functions of language, calculating and quantitative knowledge, solving problems, making decisions and reaction speed, psychomotor functions and sequencing complex movements and speed, emotional functions, perceptual functions, higher-level cognitive functions and domain-specific knowledge, experience of self and time functions and comprehension knowledge (see Appendix 3 for detailed descriptions). Users' functional operations (FO) related to human–computer interactions vary in terms of abilities in *movements, voice and sight* (McKay et al., 2012; Sevilla et al., 2007).

Human–computer ***interaction*** (IP) involves three basic human processes: sensory perception (IP1), cognition (IP2) and functional operation (IP3) (Babu et al., 2010; Gerlach & Kuo, 1991; McKay et al., 2012; Schomaker & Hartung, 1995). In the process of sensory perception (IP1), the user detects the **features of IT artefact** (content, presentation style, functionality, interaction style, and structure) with SP (Hassenzahl, 2003; W3C, 2018). These features can be revealed by some of the computer output media (COM) modalities (*visual, auditive, tactile, olfactory, gustatory or vestibular*) (Schomaker & Hartung, 1995). In the process of cognition (IP2), human cognition interprets COM and guides human body functions (i.e. FO) (Babu et al., 2010; Gerlach & Kuo, 1991; Schomaker & Hartung, 1995). In the process of functional operation (IP3), human FO work with computer input modalities (CIM) (Babu et al., 2010; Gerlach & Kuo, 1991; Schomaker & Hartung, 1995).

Information is a conceptual component that contains a message that the provider wants to convey. Information can be expressed via COM modalities (*visual, auditive, tactile, olfactory, gustatory or vestibular)* (Schomaker & Hartung, 1995). In practice, this refers to texts, images, videos, graphs, charts, tables, shapes, etc., which may manifest differences in their presentation style. For example, the use of colours, font size, shapes, and other elements involves accessibility features, which means that they have quality. Overall, information quality can be composed of availability, relevancy, response time, accuracy, completion, up-to-date-ness, transparency, reliability, convenience, ease of use, and, most importantly, accessibility itself (Alkhattabi et al., 2011; Culnan, 1984; Delone & McLean, 1992; Djamasbi & Tullis, 2006; Liang et al., 2017; Loiacono et al., 2013). Information quality in terms of accessibility means that users' SP and cognitive abilities are considered. Good information quality increases users' perception of benefit and mitigates the perception of fake information risk (Liang et al., 2017). Information quality also has a positive impact and relationship to the state of actual use and user satisfaction (c.f. IS Success Model by Delone & McLean, 1992). Moreover, information convenience and reliability, which are features of information quality, have a positive impact on users' perception of ease of use, usefulness and intention-to-use (c.f. TAM by Davis et al., 1989) (Loiacono et al., 2013).

Accessibility features themselves improve information perception. This means that information quality can be improved by implementing accessibility features. For example, intrinsic, contextual accuracy and completeness can be improved with context-sensitive design and factors related to information architecture. According to Liang et al. (2017), the level of disability affects how a user perceives information quality and system quality. As an example, Liang et al. (2017) argued that people with severe degrees of disability do not notice a significant difference in the risks posed by a fake website if the quality of information is high or low. However, if the quality of the system is high or low, it has a strong positive effect on detecting the risks of fake websites. This can be dangerous because, for example, fake websites can easily give the impression of a high system quality that users rely on to assess risk (Liang et al., 2017). System quality is a multidimensional factor, but from an accessibility perspective, accessibility itself is the strongest predictor of system quality (Liang et al., 2017). Furthermore, other factors of system quality, such as fastness, navigability and readability of the content, can be improved through accessibility features. For example, fastness can be improved by reducing cognitive load and improving remembering (Sayago & Blat, 2010; Sharlin et al., 2009). Navigability can be improved by several accessibility factors related to, for example, linearity of navigation (Vigo & Harper, 2013), customisation (Harper & Bechhofer, 2007) or naming (Aizpurua et al., 2016). The readability of the content can be improved with the bilingual approach and factors related to information architecture (Aizpurua et al., 2016; Berget et al., 2016; Hammami et al., 2019; Sayago & Blat, 2010).

To support users' task performance (TP), ***tasks*** should be designed considering users' abilities to perceive and recognise the system stage; interpret and understand the meaning of the message; evaluate the system stage and understand the consequences with respect to the established goals and intentions; and physical activities (Carroll, 1993; Gerlach & Kuo, 1991; Norman, 1986). Moreover, complex tasks should be broken down into smaller chunks with precisely defined tasks and gamification elements characterising the tasks should be added to gain motivation and engagement. Thus, task characteristics influence users' goal setting and intention to perform tasks (Jackson et al., 2015; Prestopnik et al., 2017; Sprinks et al., 2017; Tinati et al., 2017; Zhou et al., 2017).

Context of use (CU) may vary due to environmental factors, including users' emotional state, socio-cultural factors and socio-technical factors, whereby the cultural, political, sociological and historical aspects of the context influence the users (Lyytinen & Newman, 2008; McKay et al., 2012; Meiselwitz et al., 2010; Sharp et al., 2020; WHO, 2013). The context of use influences users' abilities. Moreover, users' expectations based on past experiences, prejudices, evoked memories, unmet expectations and confidence strongly affect how users perceive and experience the accessibility of websites (Aizpurua et al., 2015). Expectations can be interpreted to be a part of context history, affecting users' emotional state (for example, users' feelings of dread).

4.1 Positioning the AM for Technology Acceptance

Accessibility is a fundamental factor in technology acceptance (Culnan, 1984; Djamasbi & Tullis, 2006; Loiacono et al., 2013), so the next step is to demonstrate the position of the AM in user behaviour in the technology acceptance process. I compare the AM to well-known TAMs (Davis et al., 1989) and related studies to discuss the relationship between accessibility and usability.

TAMs (Davis et al., 1989) provide theories to explain and predict user acceptance to expand the knowledge on why people accept or reject new technology. The original TAM posits two primary relevance for technology acceptance, namely, perceived usefulness (PU) and perceived ease of use (PEU), which both influence users' attitudes towards use (Davis, 1993; Davis et al., 1989). In the TAM, internal beliefs, attitudes and intentions are considered external variables, where individual differences are seen as impingements on user behaviours (Davis et al., 1989). System features as external variables are considered for improving usability that influences *perceived usefulness* and *perceived ease of use*. A study by Venkatesh and Davis (2000) expanded TAM with a cognitive instrumental process that impacts *perceived usefulness*. The cognitive instrumental process includes job relevance, output quality, result demonstrability and *perceived ease of use* (Venkatesh & Davis, 2000). Venkatesh and Bala (2008) extended the original TAM by defining the determinants for *perceived ease of use*, which are computer self-efficacy, computer anxiety, computer playfulness and perceptions of external control. However, neither this extension nor TAM considers possible users' disabilities (Djamasbi & Tullis, 2006). However, users' individual differences are considered in computer self-efficacy in terms of individuals' beliefs about their ability to use the system (Venkatesh & Bala, 2008). Furthermore, objective usability represents one of the system's characteristics related to adjustments, whereby users are expected to gain experience with system use (Venkatesh & Bala, 2008). In the study by Venkatesh and Bala (2008), usability was considered an anchor of *perceived ease of use*, whereas Nielsen (1993) believed that all usability features promote usefulness. Meanwhile, Lin (2013) tested the relationship between TAM and usability and found no significant causality between *perceived usefulness* and usability (effectiveness and efficiency). Instead, a correlation was found between *perceived ease of use* and usability attributes of learnability and memorability. In the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003), age, gender, experience and voluntariness of use are considered moderating variables between effort expectancy (dependent variable) and behavioural intention (independent variable). Effort expectancy refers to the degree of easiness of system use containing *perceived ease of use* (Venkatesh et al., 2003). In UTAUT, all moderating variables that refer to individual differences have an impact between effort expectancy and behavioural intention. However, from these individual differences, only age can be considered a factor in accessibility when other individual differences are ignored.

In conclusion, the usability features affecting *perceived ease of use* are learnability and memorability, which both require users' cognitive effort (Cinquin et al., 2019; Davis, 1993; Nielsen, 1993). Moreover, users should be able to accomplish tasks without much cognitive effort to gain efficiency in use (Leuthold et al., 2008). In this case, the focus of cognitive effort refers to users' cognitive abilities and, thus, to accessibility. Therefore, appropriate adjustments of system features, such as usability features, to meet users' abilities can make *perceived usefulness* and *perceived ease of use* more possible for those whose abilities are considered in the IT artefact design process. Thus, accessibility can be considered a moderating variable between systems features (independent variable) and *perceived usefulness* and *perceived ease of use* (dependent variables). Considering IT artefact features as independent variables may present all the features that IT artefacts consist of. In fact, according to the AM, IT artefact features reveal the COM and CIM.

5 DISCUSSION

This article develops an explanation of accessibility, its constructs, and their relationships. Moreover, accessibility's interconnection to usability is discussed within the proposed model. The purpose of this model is to increase the rigorousness of accessibility-related research to assess the contribution of AM with regards to previous descriptions of accessibility. Thereafter, the relationship to usability is discussed.

5.1 A Richer Description of Accessibility

There is a consensus in the literature on the definition of the desired extent of accessibility. In fact, studies rely on the definitions stated in the ISO standard and in accessibility approaches, such as Universal Design and Design for all, among others (Persson et al., 2014). According to Sevilla et al. (2007), accessibility can be divided into interaction and access between software and hardware; browser features and user agents, AT, and web navigation technology; and user interaction with web content and structure. Culnan (1984) described accessibility in dimensions as the use of a computer (physical dimension), a user's interaction with 'non-natural language' (interface dimension) and a user's ability to retrieve information independently (informational dimension). In AM, these dimensions are embedded and described as follows. The physical dimension represents FO that interact with CIM. Meanwhile, the interface dimension represents interaction processes: the process of sensory perception (IP1), the process of cognition (IP2), and the process of functional operation (IP3). Finally, the informational dimension represents varieties in users' abilities (UA). AM is focused on describing user abilities in human–computer interactions, so it ignores interactions between the software and hardware, including AT interaction with a computer. However, AM explains the relationship among user abilities, ITAF, COM and CIM, thereby revealing the connection of these domains. AM extends the HCI model by Schomaker and Hartung (1995) with the CHC theory (McGrew, 2009) and ICF classifications (WHO,

2021) of cognitive abilities. Moreover, AM considers the task performance and related processes. Gerlach and Kuo (1991) described similar user task performance behaviours in HCI but did not intend to describe all variables in user abilities, tasks or contexts.

A challenging task in accessibility design is setting the COM to match users' varying abilities in SP and setting the CIM to match the user's FO channels. In addition, probably the most challenging task is providing information of such quality through COM in such modalities that match the users' varying cognitive abilities. Therefore, as an ideal script for information accessibility, the COM should be designed first, such that they are perceivable with any variable in a user's SP. In addition, the COM should be designed such that it also matches the variables in users' cognitive abilities. AM considers information as a conceptual component that can be presented via ITAF revealed by the COM. Information quality in terms of accessibility means that users' sensory perceptions and cognitive abilities are considered. The information quality can be composed of availability, relevancy, response time, accuracy, completion, up-to-date-ness, transparency, and, most importantly, accessibility itself (Alkhattabi et al., 2011; Culnan, 1984; Delone & McLean, 1992; Djamasbi & Tullis, 2006; Liang et al., 2017). Then, the CIM should be designed such that it is able to receive possible human outputs like movements, force, sound or image that input devices (pointing devices, keyboards, microphones, cameras, sensors, etc.) can measure (Schomaker & Hartung, 1995).

5.2 Relationship Between Accessibility and Usability

The relationship between accessibility and usability in prior studies is holistic and, thus, vague. For example, concepts that integrate accessibility, usability and UX in one experience have been presented (c.f. Sauer et al., 2020). Some of the prior studies emphasise the importance of jointly considering and addressing usability and accessibility to provide usability to as many people as possible regardless of their abilities (Aizpurua et al., 2016; Cairns et al., 2019; Giraud et al., 2018; Leuthold et al., 2008; Link et al., 2006; Martins et al., 2017; Ruiz et al., 2011; Santana & Baranauskas, 2015; Vollenwyder et al., 2019). On the other hand, some prior studies consider accessibility as a precondition to usability (Davis et al., 1989; Iwarsson & Ståhl, 2003; McKay et al., 2012; Meiselwitz et al., 2010). As a response, AM proposes a more rigorous description of the interconnection between accessibility and usability. According to Lin (2013), the usability features that affect *perceived ease of use* are at least *learnability* and *memorability*, both of which require users' cognitive effort (Davis, 1993; Nielsen, 1993). Moreover, efficient use means that users should accomplish their tasks without much cognitive effort (Leuthold et al., 2008). The requirements for cognitive effort are linked to accessibility. Hence, AM provides a more in-depth description: the adjustment of usability features to meet individual requirements makes *perceived usefulness* and *perceived ease of use* more possible to people for whom abilities are considered in the IT artefact design process. Thus, accessibility is a moderating variable between IT artefact features (independent variable)—in this case, usability)—and *perceived usefulness* and *perceived ease of use* (dependent variables).

Prior studies recommend multimodality as a step towards universal access (c.f. Alghabban et al., 2017; Barreto et al., 2007; Cairns et al., 2019; Ferres et al., 2013; Giraud et al., 2018; Raisamo et al., 2019; Ruiz et al., 2011; Sevilla et al., 2007). I agree with these studies. AM describes multimodality in COM and CIM similar to Schomaker & Hartung (1995), but it also presents variables related to user abilities to illustrate the fit between user abilities and multimodality. For example, Obrenovic et al. (2007) presented a framework to identify if the designed interface is appropriate for a particular situation and how one interaction modality affects a user's abilities, such as cognitive factors as a whole. However, according to Berget et al. (2016) and Sevilla et al. (2007), issues relating to cognitive deficits are necessary to consider as specific individual cognitive deficits rather than cognitive matters as a whole. Therefore, AM presents possible variables in cognition and does not consider it as a whole. As a contribution to the universal aspect, AM shows the constructs stated in the definition of accessibility and the domains of possible variables and their relationship with other variables. With AM, researchers can identify variables in user abilities, interaction processes, tasks, and contexts more accurately. Based on the results of this study, I claim that in practice, access and use of information concerning all variations in user abilities in any task and context are difficult to achieve using just one solution but not impossible at a theoretical level.

5.3 Limitations and Future Research

This study has limitations. The construction of the AM relies on certain studies from which theories are extracted and integrated into the model. These prior theories represent constructs (i.e. building blocks) of AM and can be considered as samples. Therefore, AM does not attempt to be a comprehensive presentation. However, selected references for AM are published in highly reputable IS or HCI journals or are well-known in practice. Next, the AM has not been tested empirically, so I cannot claim that the proposed model is the best solution. However, I hope that the model will provide an understanding of user abilities and their relationships with interaction, as well as usability among researchers, helping them define and communicate the research focus and its relationships more rigorously. The nature of AM is explanatory. Thus, it describes what accessibility is and tells us how something should or could be done. However, the AM is a conceptual model. For example, the AM tells us how to design COM using visual, auditory, tactile, olfactory, gustatory or vestibular presentational style of information to meet user abilities (sensory perceptions, cognition and functional operations). Practical methods and techniques to say how to do this in practice warrant more research and are scoped for future investigations.

The next avenue for accessibility and multimodality research should address the level of abilities and how far technology can be developed to support users with severe disabilities and their autonomous IT use. This paper calls for a research stream for universal accessibility. Using the AM, the desired extent of universal accessibility, including any changes in user ability and context, can be investigated using the AM as follows:

- How should COM be formalised to match users' varying abilities in SP?
- How should CIM be designed to match users' varying FO channels?
- How should information be expressed through COM so that users with varying cognitive abilities can understand and use it?

6 CONCLUSION

Prescriptive theories of accessibility can help researchers align their intended research focus with the full picture of accessibility. This means that researchers could identify possible variables and relationships related to human abilities, tasks, and contexts of use. Few publications in IS and HCI field have discussed these variables and relationships. In this article, I described the constructs of accessibility. I illustrated possible variables in human abilities, tasks, and contexts of use and how their relationship is constructed. Next, I discussed the difference between accessibility and usability in user acceptance and argued that accessibility is a moderating variable between IT artefact features, in this case, usability, and perceived usefulness and perceived ease of use. Therefore, accessibility is a major determinant of user acceptance.

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Appendix 1. ICF Classification of Human Body Functions (WHO, 2021; World Health Organization, 2002, 2013)

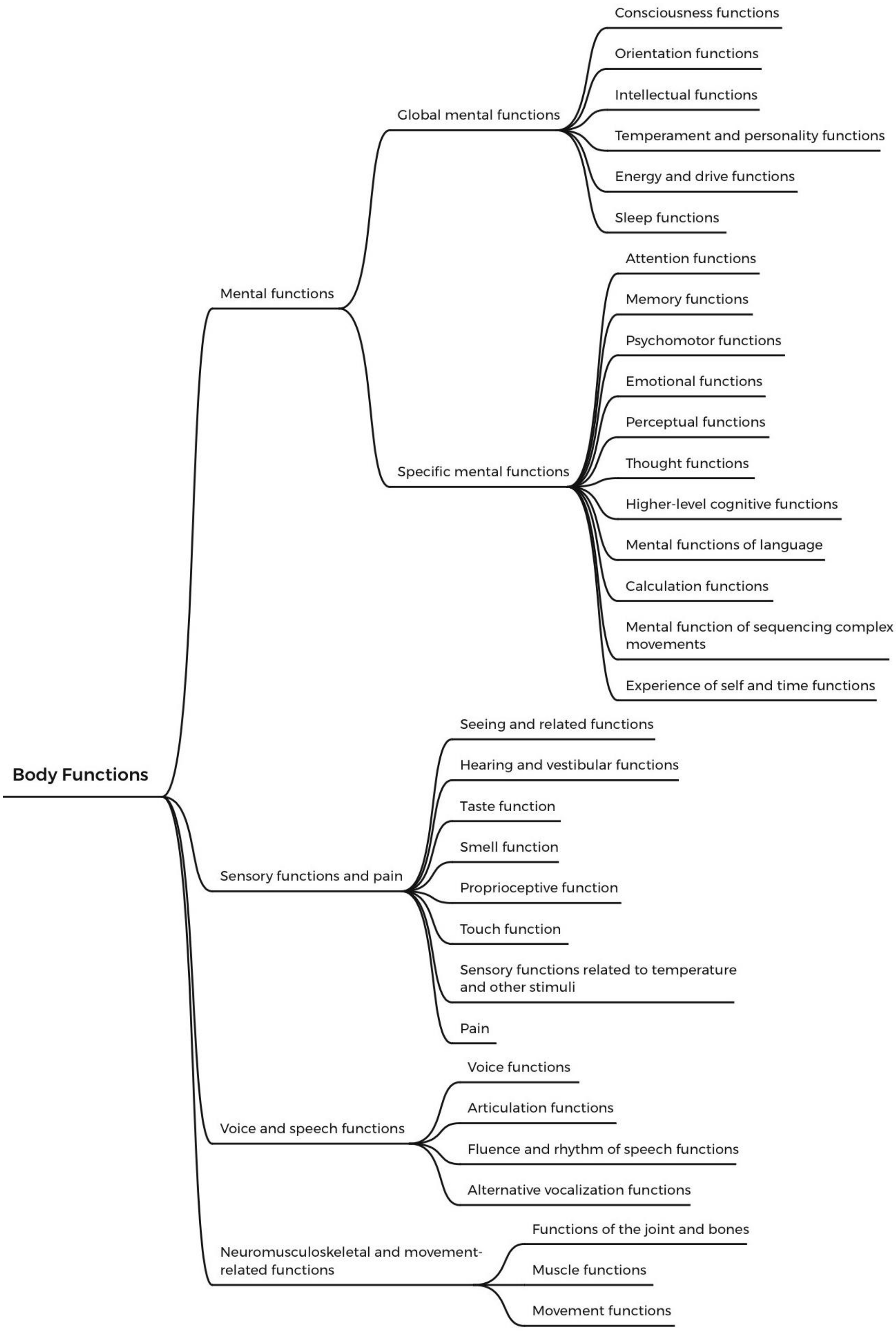

Figure A 1. ICF Classification of Body Functions Taxonomy

Appendix 2. ICF Classification of Human Abilities for Activities and Participation (WHO, 2021; World Health Organization, 2002, 2013)

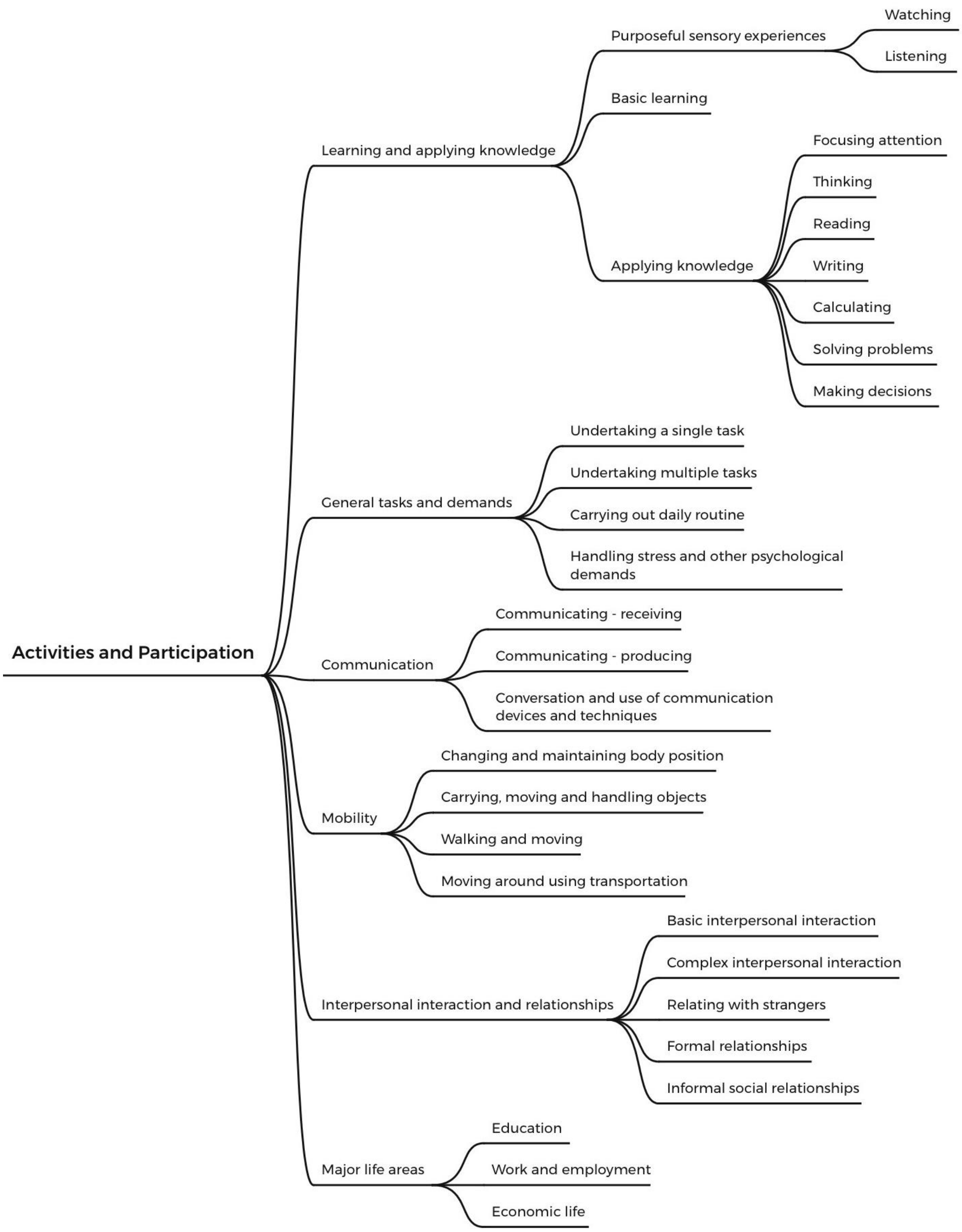

Figure A 2. ICF Classification of Activities and Participation Taxonomy

Appendix 3. Unified Classification of Human Cognitive Abilities

The Cattell-Horn-Carroll (CHC) theory of cognitive abilities within original codes (McGrew, 2009), domains in ICF Mental Functions and domains in ICF Applying Knowledge, including the original ICF browser codes from the International Classification of Functional Abilities by the World Health Organization (WHO, 2021) are extracted and presented in Table A1.

Table A 1. Unified Classification of Human Cognitive Abilities

Cattell-Horn-Carroll (CHC)	**ICF Mental Functions**	**ICF Applying Knowledge**	**Unified Classification of Cognitive Abilities**	**Description (quotations of related ability)**
-	Attention functions (b140)	Focusing attention (d160)	Focusing attention	'Specific mental functions focusing on an external stimulus or internal experience for the required period of time' (b140); 'Intentionally focusing on specific stimuli, such as by filtering out distracting noises' (d160)
Short-term memory (Gms) Long-term storage and retrieval (Glr)	Memory functions (b144)	-	Memory	'The ability to comprehend and maintain awareness of a limited number of elements of information in the immediate situation (events that occurred in the last minute or so)' (Gms); 'The ability to store and consolidate new information in long-term memory and later fluently retrieve the stored information (e.g. concepts, ideas, items, names) through association' (Glr); 'Specific mental functions of registering and storing information and retrieving it as needed' (b144)
Processing speed (Gs)	Thought functions (b160)	Thinking (d163)	Thinking and speed of processing	'The ability to automatically and fluently perform relatively easy or over-learned elementary cognitive tasks, especially when high mental efficiency (i.e. attention and focused concentration) is required (Gs); 'Specific mental functions related to the ideational component of the mind. Inclusions: functions of pace, form, control and content of thought; goal-directed thought functions, non-goal-directed thought functions; and logical thought functions, such as pressure of thought, flight of ideas, thought block, incoherence of thought, tangentiality, circumstantiality, delusions, obsessions

				and compulsions' (b160); 'Formulating and manipulating ideas, concepts and images, whether goal-oriented or not, either alone or with others, such as creating fiction, proving a theorem, playing with ideas, brainstorming, meditating, pondering, speculating or reflecting' (d163)
Reading and writing (Grw)	-	Reading (d166); Writing (d170)	Reading and writing	'The breadth and depth of a person's acquired store of declarative and procedural reading and writing skills and knowledge' (Grw); 'Performing activities involved in the comprehension and interpretation of written language (e.g. books, instructions or newspapers in text or Braille) for the purpose of obtaining general knowledge or specific information (d166); 'Using or producing symbols or language to convey information, such as producing a written record of events or ideas or drafting a letter' (d170)
-	Mental functions of language (b167)	-	Mental functions of language	'Specific mental functions of recognising and using signs, symbols and other components of a language. Inclusions: functions of reception and decryption of spoken, written or other forms of language, such as sign language; functions of expression of spoken, written or other forms of language; integrative language functions spoken and written, such as those involved in receptive, expressive, Broca's, Wernicke's and conduction aphasia' (b167)
Quantitative knowledge (Gq)	Calculation functions (b172)	Calculating (d172)	Calculating and quantitative knowledge	'The breadth and depth of a person's acquired store of declarative and procedural quantitative or numerical knowledge' (Gq). 'Specific mental functions of determination, approximation and manipulation of mathematical symbols and processes. Inclusions: functions of addition, subtraction and other simple mathematical calculations; functions of complex mathematical operations' (b172). 'Performing computations by applying mathematical principles to solve problems that are described in words and producing or displaying the results, such as computing the sum of three numbers or finding the result of

				dividing one number by another' (d172).
Fluid reasoning (Gf)	-	Solving problems (d175)	Solving problems	'The use of deliberate and controlled mental operations to solve novel problems that cannot be performed automatically' (Gf). 'Finding solutions to questions or situations by identifying and analysing issues, developing options and solutions, evaluating potential effects of solutions, and executing a chosen solution, such as resolving a dispute between two people. Inclusions: solving simple and complex problems' (d175).
Reaction and decision speed (Gt)	-	Making decisions (d177)	Making decisions and reaction speed	'The ability to make elementary decisions and/or responses (simple reaction time) or one of several elementary decisions and/or responses (complex reaction time) at the onset of simple stimuli' (Gt). 'Making a choice among options, implementing the choice, and evaluating the effects of the choice, such as selecting and purchasing a specific item, or deciding to undertake and undertaking one task from among several tasks that need to be done' (d177).
Psychomotor abilities (Gp); Psychomotor speed (Gps)	Psychomotor functions (b147); Mental function of sequencing complex movements (b176)	-	Psychomotor functions and sequencing complex movements and speed	'The ability to perform physical body motor movements (movement of fingers, hands, legs, etc.) with precision, coordination or strength' (Gp). 'The ability to rapidly and fluently perform physical body motor movements (movement of fingers, hands, legs, etc.) largely independent of cognitive control' (Gps). 'Specific mental functions of control over both motor and psychological events at the body level. Inclusions: functions of psychomotor control, such as in psychomotor retardation, excitement and agitation, posturing, catatonia, negativism, ambitendency, echopraxia and echolalia; quality of psychomotor function' (b147). 'Specific mental functions of sequencing and coordinating complex, purposeful movements. Inclusions:

				impairments, such as ideation, ideomotor, dressing, oculomotor and speech apraxia' (b176).
-	Emotional functions (b152)	-	Emotional functions	'Specific mental functions related to the feeling and affective components of the processes of the mind. Inclusions: functions of appropriateness of emotion, regulation and range of emotion; affect, sadness, happiness, love, fear, anger, hate, tension, anxiety, joy, sorrow; lability of emotion; and flattening of affect' (b152).
Tactile abilities (Gh); Kinaesthetic abilities (Gk); Olfactory abilities (Go)	Perceptual functions (b156)	-	Perceptual functions	'Abilities involved in the perception and judging of sensations that are received through tactile (touch) sensory receptors' (Gh). 'Abilities that depend on sensory receptors that detect bodily position, weight or movement of the muscles, tendons and joints' (Gk). 'Abilities that depend on sensory receptors of the main olfactory system (nasal chambers)' (Go). 'Specific mental functions of recognising and interpreting sensory stimuli. Inclusions: functions of auditory, visual, olfactory, gustatory, tactile and visuospatial perception, such as in hallucinations or illusions' (b156).

General (domain-specific) knowledge (Gkn)	Higher-level cognitive functions (b164)	-	Higher-level cognitive functions and domain-specific knowledge	'The breadth, depth and mastery of a person's acquired knowledge in specialised (demarcated) subject matter or discipline domains that typically do not represent the general universal experiences of individuals in a culture' (Gkn). 'Specific mental functions, especially dependent on the frontal lobes of the brain, including complex goal-directed behaviours such as decision-making, abstract thinking, planning and carrying out plans, mental flexibility, and deciding which behaviours are appropriate under what circumstances; these are often called executive functions. Inclusions: functions of abstraction and organisation of ideas; time management, insight and judgement; concept formation, categorisation and cognitive flexibility' (b164).
-	Experience of self and time functions (b180)	-	Experience of self and time functions	'Specific mental functions related to the awareness of one's identity, one's body, one's position in the reality of one's environment and time. Inclusions: functions of experience of self, body image and time' (b180).
Comprehension-knowledge (Gc)	-	-	Comprehension-knowledge	'The knowledge of the culture that is incorporated by individuals through a process of acculturation' (Gc).

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Factors Affecting the Accessibility of IT Artifacts: A Systematic Review

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Abstract:

Accessibility awareness and development have improved in the past two decades, but many users still encounter accessibility barriers when using information technology (IT) artifacts (e.g., user interfaces and websites). Current research in information systems and human-computer interaction disciplines explores methods, techniques, and factors affecting the accessibility of IT artifacts for a particular population and provides solutions to address these barriers. However, design realized in one solution should be used to provide accessibility to the widest range of users, which requires an integration of solutions. To identify the factors that cause accessibility barriers and the solutions for users with different needs, a systematic literature review was conducted. This paper contributes to the existing body of knowledge by revealing (1) management- and development-level factors, and (2) user perspective factors affecting accessibility that address different accessibility barriers to different groups of population (based on the International Classification of Functioning by the World Health Organization). Based on these findings, we synthesize and illustrate the factors and solutions that need to be addressed when creating an accessible IT artifact.

Keywords: Accessibility, Web accessibility, Accessible IT Artifacts, Systematic Literature Review.

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This manuscript underwent [editorial/peer] review. It was received xx/xx/20xx and was with the authors for XX months for XX revisions. [firstname lastname] served as Associate Editor.] **or** The Associate Editor chose to remain anonymous.]

1 Introduction

Designing IT artifacts[1] that are accessible to all people is a difficult task (Meiselwitz, Wentz, & Lazar, 2010). A well-known ISO standard (ISO 9241–11:2018) defines accessibility as the "extent to which products, systems, services, environments, and facilities can be used by people from a population with the widest range of user needs, characteristics, and capabilities to achieve identified goals in identified contexts of use" (International Organization for Standardization, 2018). Legislation and standards of accessibility globally enforce the need for public sector actors, in particular, to provide accessible web services. The importance of accessibility is no longer a question; rather, the question is now how to achieve and design IT artifacts that are accessible to users with different abilities and usable by the widest possible range of users (Persson, Åhman, Arvei Yngling, & Gulliksen, 2014).

Nearly two decades ago, Lazar et al. (2004) estimated that 70–98% of websites were not accessible. Since then, accessibility guidance has experienced remarkable enhancements. For instance, the Web Accessibility Initiative's Web Content Accessibility Guidelines (WCAG) have had two major updates: WCAG 2.0 (2008) and WCAG 2.1 (2018). The ISO standard of accessibility had its latest update in 2019 (ISO/IEC 30071-1:2019). In Europe, the European EN standard of accessibility, EN 301 549 V1.1.2 (2015–04), served as the basis for the EU directive on the accessibility of websites and mobile applications of public sector bodies (Directive 2016/2102., 2016). The EU directive has been localized to national legislation in EU countries. The accessibility guidance behind the regulations is based on the WCAG guidelines. It is notable that transforming WCAG-complied webpages to correspond with updated versions does not require a full revision of the webpages (S.-H. Li, Yen, Lu, & Lin, 2012).

As evidenced by this progress, awareness of accessibility at the government level and willingness to make improvements have grown over the past two decades. Unfortunately, most websites remain inaccessible (Brajnik, Yesilada, & Harper, 2011; Martins, Gonçalves, & Branco, 2017; Santana & Baranauskas, 2015; Vollenwyder, Iten, Brühlmann, Opwis, & Mekler, 2019). This may be due to insufficient accessibility knowledge, confusing guidelines, poor support by management, lack of time (Lazar et al., 2004; Vollenwyder et al., 2019), lack of consideration of human diversity in the web design process (Aizpurua, Harper, & Vigo, 2016), and lack of methods and tools to correct accessibility problems (Paiva, Freire, & de Mattos Fortes, 2021). Potential accessibility problems may occur at the individual, technological, or organizational level, or somewhere in between these. This places information systems (IS) research in an important role, as these are the core focuses of IS (Myers, 1997). Moreover, the IS discipline is constantly facing new technological artifacts, which prompt the need for new research (Rowe, 2012).

In addition, the Association of Information Systems (AIS) code of ethics states: "Technologies and practices should be as inclusive and accessible as possible and scholars and computing professionals should take action to avoid creating systems or technologies that disenfranchise or oppress people" (AIS, 2021-a; Hanson, 2017). This raises the importance of addressing accessibility in IS research. A multitude of accessibility-related studies have explored how to design IT artifacts (i.e., websites, user interfaces [UI], and applications) for use by users with disabilities in a specific target population (Mack et al., 2021). Moreover, the literature presents techniques and methods that can be applied to capture a specific user population's needs successfully (c.f., Link et al., 2006; Paiva et al., 2021). However, we argue that this knowledge is fragmented. There is a gap in our knowledge of the overall factors that affect the realization of accessibility in IT artifact development and the factors that cause accessibility barriers from the user perspective of different stakeholders (Lazar et al., 2004; Leuthold, Bargas-Avila, & Opwis, 2008; Vollenwyder et al., 2019). This constitutes a gap in our knowledge of how to develop IT artifacts that are accessible regardless of ability or disability. This gap motivated us to conduct a systematic literature review (SLR) of accessibility in the top and tier-2 IS outlets and top Human-computer interaction (HCI) outlets recommended by AIS. In this paper, we summarize prior knowledge in IS and HCI and synthesize factors affecting accessibility from different stakeholders.

[1]An IT artifact is defined as an application (e.g., web application, web site, or user interface) of an IT that enables or supports a specified task embedded within the structure in a specified context (Alter, 2008).

In this study, we aim to advance accessibility by clarifying the existing evidence of factors that cause accessibility problems. We aim to extend the knowledge about the overall factors around accessibility that are related to development and human abilities and diversities and that cause accessibility barriers in IT use. Therefore, we ask:

> **What factors cause accessibility problems, and what does the literature suggest be done to address these?**

This study provides a summary of existing evidence of the factors and solutions related to accessibility issues at the individual and organizational levels. Individual accessibility needs are based on the classification of human abilities by the International Classification of Functioning, Disability, and Health (ICF). Finally, the results are synthesized, and the factors and solutions affecting accessibility are illustrated.

This paper is structured as follows. Chapter 2 presents the background of accessibility and related literature. Chapter 3 describes the SLR process. Our results are presented in Chapter 4. Chapter 5 describes the synthesized research findings. Chapters 6 and 7 present the discussion and concluding remarks.

2 Background and Related Literature Reviews

In accessibility research, the WCAG is considered one of the major accessibility guidelines in web development globally (Martins et al., 2017). There are three levels of WCAG requirements, ranging from A (lowest) to AAA (highest). The AA level is required in EU legislation. Guidelines are organized into four principles: perceivable, operable, understandable, and robust (W3C, 2018). These requirements outline how to make web content more accessible to people with disabilities. They address all web pages, documents, and embedded software that are rendered or intended to be rendered within the web pages. In addition, WCAG 2.0 is also standardized as the ISO/IEC 40500:2012 standard (International Organization for Standardization, 2012).

With respect to the difference and acceptance of persons with disabilities as part of human diversity and humanity, the United Nations' Convention on the Rights of Persons with Disabilities defines persons with disabilities as "those who have 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, 2006). Disability is a complex phenomenon that reflects a person's functional ability to interact with their environment, including their social context. Aspects of disability may vary from entirely internal to entirely external (Newman, Browne-Yung, Raghavendra, Wood, & Grace, 2017; World Health Organization [WHO], 2002). To classify a person's functional abilities in this study, we used the ICF, agreed upon by the World Health Assembly in 2001 (WHO, 2013). The ICF provides an ontological tool for understanding functioning in a society with a focus on health, functioning, and a person's abilities, rather than focusing on disabilities that may risk separating people into different categories (WHO, 2002). Thus, the ICF helps us to understand human diversities and to collect knowledge of the needs of individuals based on impairments or complex disorders. The ICF can support eligibility assessments, service planning, and system-based data generated by administrative processes (WHO, 2013) to assess whether the needs of the individual require changes in the design or provision of personal support for system use.

The ICF proposes two conceptual models of disability. First, the medical model defines disability as a feature of the person caused by disease, trauma, or other health condition requiring medical treatment to "heal" the individuals (WHO, 2002). Second, the social model sees disability as a socially created problem in which an unaccommodating environment is created by neglecting the rights of persons with disabilities (WHO, 2002). Finally, the ICF provides an intergraded model of disability that considers both the medical and social models, including biological, psychological, and social perspectives. This so-called bio-psychosocial model of disability is organized into two parts: (1) functioning and disability, which includes body functions and structures, and activities and participation; and (2) contextual factors, including environmental factors and personal factors (WHO, 2021; WHO, 2013). Notably, the UN's Convention of the Rights of Persons with Disability (United Nations, 2006) promotes the design and development of accessible information and communications to ensure equal access for all people. This includes ITs, assistive technologies (AT), and systems, meaning that the convention supports the provision of accessible IT artifacts.

Previous accessibility-related literature reviews have examined issues related to methods, techniques, and WCAG conformity. For example, Paiva et al. (2021) conducted an SLR (*N* = 94) on accessibility inclusion in software engineering, different phases of the software process life cycle, and methods used in studies published 2011–2019. The phases included requirements, design, implementation, testing, maintenance, process establishment, training, measurement, process improvement, and testing and design processes (Paiva et al., 2021). They found that, for the last decade, research on the inclusion of accessibility in software development had focused mainly on testing and design processes to conform to the needs of users with visual impairment rather than hearing impaired or cognitively disabled groups (Paiva et al., 2021). Similarly, a literature survey by Mack et al. (2021) revealed that 43% of the accessibility studies reviewed focused on accessibility for blind and low-vision people. They also confirmed that the most popularly used methods focused on design, evaluation, and user studies with a median sample size of 13 participants. They analyzed 836 papers that appeared in the proceedings of the Association for Computing Machinery (ACM) Conference on Human Factors in Computing Systems (ACM CHI) and the ACM Conference on Accessible Computing (ASSETS) from 1994 to 2019 and quantified the papers' target populations, goals, and methods.

An SLR (*N* = 58) by Ordoñez et al. (2020) investigated studies published between 2010 and 2018 related to the model-driven development of accessible software and found that many of the proposed recommendations included the use of the WCAG. WCAG conformity seems to be an area that has received significant attention in accessibility research. According to the SLRs conducted by Campoverde-Molina et al. (2020) (*N* = 25, 2009–2019) and Zhang et al. (2020) (*N* = 31, 2009–2019), educational websites and open educational resources often fail to meet WCAG requirements. However, accessibility can be improved by using automated and manual expert evaluations of WCAG principles (Campoverde-Molina, Luján-Mora, & Valverde, 2020). The SLRs carried out by Ordoñez et al. (2020), Campoverde-Molina et al. (2020), and Zhang et al. (2020) all found that the majority of studies suggested using the WCAG to improve accessibility.

In an SLR by Cinquin et al. (2019) (*N* = 29, 2011–2017), the authors aimed to develop a better understanding of online e-learning platform accessibility for people with cognitive impairments. Their results indicate a weak inclusion of accessibility standards and concern that studies often tend to provide design recommendations rather than evaluating the effectiveness of e-learning platforms (Cinquin et al., 2019). In addition, many scholars argue that even full compliance with existing accessibility standards or guidelines does not guarantee a full scope of accessibility or usability or a good user experience (UX) of a website (Aizpurua, Arrue, & Vigo, 2015; Babu, Singh, & Ganesh, 2010; Lazar et al., 2004; Leuthold et al., 2008; Martins et al., 2017; Petrie, Hamilton, & King, 2003). For example, only about 50% of the problems encountered by blind users have been found to be covered by and related to WCAG checkpoints (Petrie et al., 2003; Vigo & Harper, 2013). Furthermore, most of the approaches that have implemented these standards are based on economically unrealistic models and have therefore been ignored (Leuthold et al., 2008).

In conclusion, prior research has focused on testing, designing processes, methods, and WCAG conformity, investigating who is included, what methods and tools are used, and what issue is addressed. To our knowledge, no published study has looked at the combination of factors that affect accessibility at the development and management levels and factors that cause accessibility barriers for users. To address this gap, this paper presents an SLR that aims to clarify the factors behind accessibility problems and the suggestions presented in the literature for addressing these issues.

3 Systematic Literature Review Methodology

Inspired by suggestions by Kitchenham and Charters (2007) and Okoli (2015) on how to conduct an SLR, we set a four-phase research protocol for our purposes. In general, the phases recommended by the authors involve planning, search and selection, data extraction, synthesis, and reporting. Therefore, we set our study in the following phases: (1) planning the review phase, (2) conducting the review phase (including three steps), (3) data extraction phase, and (4) data synthesis phase (Table 1). In the following chapters, we describe our SLR protocol and phases in detail.

Table 1. Procedure for Conducting the Systematic Literature Review

Phase	Phase Content	Phase Result
Planning the review	Identifying keywords, journal-selection from academic journal guide 2021, development of the review protocol.	Review protocol
Conducting the review (steps 1, 2, and 3)	Step 1: Conduct the search (First hits: 1476 articles), review title, abstract, and keywords. Exclusion criteria: keyword not found, literature review, editorial, opinion, commentary, short paper. Step 2: Review introduction and conclusions. Exclusion criteria: not focused on accessibility. Step 3: Review full article. Exclusion criteria: focus is not on accessibility in the sense of HCI.	Step 1: 398 articles Step 2: 131 articles Step 3: 82 articles
Data Extraction	Extract data with coding scheme (presented in Table 2).	Attributes collected from the primary studies.
Data Synthesis	Synthesize extracted data.	Domains, factors, roles and actions, solutions, and relationships identified.

3.1 Planning Phase

In the planning phase, we prepared a search protocol that consisted of a search strategy (keywords, database, and review protocol). We first conducted an initial search to identify relevant keywords and search strings that could be used to identify relevant studies for our purpose and objectives. We tried not to exclude potential papers in our use of keywords and string candidates; thus, instead of scoping the term to "web accessibility," we decided to use the broader term "accessibility."

We targeted research and empirical papers published in high-level journals in the IS and HCI disciplines. We selected journals recommended by the AIS Senior Scholars' Basket of Journals, as these are considered the top journals in the IS discipline (AIS, 2021-b). We selected the *European Journal of Information Systems*, *Information Systems Journal*, *Information Systems Research*, the *Journal of Association for Information Systems*, the *Journal of Information Technology*, the *Journal of Management Information Systems*, the *Journal of Strategic Information Systems*, and *Management Information Systems Quarterly*. We then selected the following tier-2 IS journals ranked by the Chartered Association of Business Schools (Academic Journal Guide 2021, 2021): *Decision Support Systems*, *Government Information Quarterly*, *Information and Management*, *Information and Organization*, *Information Society*, *Information Systems Frontiers*, *Information Technology and People*, *International Journal of Electronic Commerce*, *Internet Research*, *Journal of Computer-Mediated Communication*, and the *Journal of the Association for Information Science and Technology* (formerly the *Journal of the American Society for Information Science and Technology*). We also included top journals in the HCI discipline recommended by the AIS Special Interest Groups. These included *AIS Transactions on Human-Computer Interaction*, *ACM Transactions on Computer-Human Interaction*, the *International Journal of Human-Computer Studies*, *Human-Computer Interaction*, and *Computers in Human Behavior*. In addition, we included proceedings from the International Conference on Information Systems.

We then planned a review protocol. For our search, we used the AIS eLibrary and the journals' or conference's websites or portals. We collected articles published between 2000 and 2020. In our review protocol, we agreed to conduct the review in three steps. First, we collected articles featuring the search keyword "accessibility" in the title, abstract, or keywords. We excluded literature reviews, editorials, opinions, commentaries, and short papers. Second, we evaluated the studies by introduction and conclusion. Third, we evaluated the studies based on a review of the full paper. We decided that every article had to be evaluated by at least two authors.

3.2 Review Phase (Steps 1, 2, and 3)

In the first step of the review phase, two of the authors conducted the search for selected journals, resulting in 1476 articles, which were divided among two authors for exclusion criteria screening. We excluded 1078 articles. The foremost reason for the exclusion of articles was improper filtering by the journal's search engine. In these cases, we screened the articles manually. At the end of step one, we had a list of 398 unique articles.

In the second step, we reviewed the selected articles' introductions and conclusions. Articles were excluded based on the focus of their content. Only studies that focused on accessibility were included. Two of the authors reviewed all the articles separately and independently from one another. The reviewers disagreed in their assessment of nine articles. To improve the quality of our review process, we reassessed articles with conflicting review results, and consensus was achieved in a meeting with all authors. Of the 398 articles reviewed, 131 were chosen for inclusion in the final step.

In the third and final step, we evaluated the articles based on their full text. Two authors conducted the evaluation, which concentrated on confirming the articles' focus on accessibility and relevance to considerations of human ability, disability, characteristics, or other diversities from the perspective of HCI. We selected 82 of the articles reviewed as primary studies. These articles were identified as relevant to our research questions and were included in the subsequent data extraction phase.

3.3 Data Extraction Phase

In the data extraction phase, we extracted information from each of the selected primary studies using an inductive approach in which we collected attributes to provide an overview of the selected studies and to collate knowledge relevant to the answer to the research question. First, we extracted descriptive attributes: journal/conference name, article title, keywords, research questions, publication year, methods, theoretical bases to have an overview of the primary studies. We then extracted attributes related to the main content of each study: main focus, main idea, contributions, future recommendations, stakeholders, and ICF coding for which we had predefined codes (Table 2).

Table 2. Coding Scheme for Data Extraction Attributes

Collected Attributes	Description of the Attribute Coded
Journal/conference name	The name of the publication venue
Article title	The title of the study
Keywords	Given keywords of the study
Research questions	Defined research questions of the study
Publication year	The year of publication
Methods	Methods applied in the study
Theoretical bases	Background theories of the study
Main focus	The focus area of the study. What is the application domain of the study? E.g., web content, game design, haptic, etc.
Main idea	The main idea of the study. What are the research aims?
Contributions	Contributions to theory and practice
Future recommendations	Provided recommendations for further research
Stakeholders	Parties related to specified group of people with disabilities
ICF coding	Specified group of people with disabilities corresponding to the ICF Browser coding scale: Body function and Structure (Mental functions; Sensory functions (seeing and related functions); Sensory functions (hearing and vestibular functions); Movement-related functions); Activities and Participation (Learning and Applying knowledge; Mobility); other

Two authors analyzed and interpreted the papers. To address our research question, we aimed to identify specific factors reported to create accessibility issues and proposed solutions. Two authors independently coded corresponding stakeholders (What human functioning or disability are concerned?), domains (Who and what factors affect accessibility?), and suggested solutions (How should the identified accessibility issue be tackled, or how should the IT artifact be designed?). We improved the accuracy of the data extraction by discussing divergent interpretations and confirming that all three authors agreed with the findings.

We focused on specific factors that cause accessibility barriers based on human functioning and disability, as these are fundamental to meeting general accessibility requirements in systems and UI designs. Thus, in order to align human functioning and disability, we modified the ICF framework to suit our research aims by including the main components of body functions (ICF code (b)) and activities and participation (ICF code (d)) (WHO, 2021). We then compared target groups from the primary studies to corresponding

ICF coding in the main categories (c.f., WHO 2021). We excluded body structures because the structure of the nervous system of an eye, for example, is irrelevant to our study purposes, and eventually, the variance in body structure reflects body functions and abilities. Furthermore, we excluded personal factors from the framework because variance in personal factors, such as age or level of stress, often appears as decreased cognitive capability. These factors were coded as Activities and Participation under the ICF Browser coding scale.

3.4 Data Synthesis Phase

In the data synthesis phase, we collated the causalities for the factors related to accessibility issues in IT artifact development and those with user perspectives. Then, we identified the corresponding stakeholders and the proposed solutions for these issues. We also categorized the elements of an IT artifact according to corresponding accessibility issues. Finally, we synthesized these findings and formulated an illustrative model to address the research question.

4 Results

In this section, we present the results of our SLR. The review phase described in Section 3.2 produced a total of 82 articles for analysis (see appendix for a list of included studies). After coding the selected papers, we identified factors at the management and development level that affect accessibility, as well as proposed solutions, which we present next in Section 4.1. In this study, we refer to developers as individuals who work at the development level, including web designers and coders. We next identified factors that cause accessibility problems in user perspective and solutions for these, which we present in Section 4.2 according to each specific body function and disability of a target group related to the ICF classifications.

4.1 Factors in Management and Development Level That Affect Accessibility and Proposed Solutions

According to Lazar et al. (2004), “accessibility is not just a high-level theoretical goal.” In the IT artifact design process, several stakeholders contribute to the design of accessible interfaces, impacting perceived web accessibility (Lazar et al., 2004; Vollenwyder et al., 2019). Lazar et al. (2004) propose a “web accessibility integration model” to improve web accessibility, which identifies three categories that influence the promotion of web accessibility: (1) societal foundations, (2) stakeholders’ perceptions, and (3) web development. Societal foundations include education and training, which influence web developers’ perceptions of web accessibility. Policy, law, and present statistics on inaccessibility influence clients’ perception of web accessibility. If neither of the two key stakeholders (web developers and clients) is aware of accessibility or willing to enhance it, the constructed website remains inaccessible (Lazar et al., 2004; Martins et al., 2017). Moreover, as the funding sources and goals of IT products in business and the public sector differ, the promotion of accessibility requires collaboration, including understanding and trust between researchers, developers, and disability advocacy organizations (Neufeldt, Watzke, Birch, & Buchner, 2007; Stienstra, Watzke, & Birch, 2007). Therefore, management and developers in the public and private sectors are in a key position to develop accessible IT artifacts. Table 3 presents a summary of domain-level factors that affect accessibility in IT artifact development. In the following subchapters, we describe each factor in detail.

Table 3. Summary of Factors in IT Artifact Development That Affect Accessibility and Solutions Proposed in the Literature

Domain	Factor(s)	Proposed Solutions	Effect	ID
Management	Support to web development	Provide education, training, manuals, and encouragement regarding accessibility that covers laws and practices of complying with guidelines and knowledge of how to apply techniques, testing methods, testing procedures, and techniques for AT compatibility (PS42, PS39, PS35, PS56, PS60, PS61, PS68) that fit local practices (PS53). Allocate time resources (PS42).	Web developers' perception of accessibility (PS42) and motivation to consider accessibility and quality of the product improved (PS35).	PS35, PS39, PS42, PS53, PS56, PS60, PS61, PS68

Management	The level of evaluators' expertise	Recruit experts to evaluate accessibility (PS82). For example, by using a barrier walkthrough method, one expert can detect 70% of the problems, two experts 94%, and three experts 100% (PS34, PS62).	Quality of measurements and validity, and reliability of the results improved (PS34).	PS34, PS62, PS82
Management	Engagement of a diverse range of stakeholders	Engage a diverse range of stakeholders, such as line managers, copywriters, and policymakers, to make accessibility a reality.	An attitude and commitment to promote accessibility.	PS59, PS64, PS65, PS72
Developers	Accessibility evaluation	Prioritize the evaluation of accessibility in general evaluation (PS75). Combine automated and manual evaluations. Automated tools can be used to identify accessibility errors violating principles (e.g., WCAG, Section 508) (PS34, PS39, PS54, PS55, PS77, PS80). These should be used regularly for new posts (PS55, PS62,). Evaluation should contain at least the homepage and first-level pages (PS78). Manual evaluation should involve a definition of the evaluation scope, techniques, and tools (e.g., user testing and result format) (PS39, PS62). Investigate client-side event logs to provide remote, informal, and asynchronous data (PS32).	Identification of accessibility errors (PS34, PS39, PS54, PS75), an understanding of characteristics and identification of barriers of event streams related to AT with real task performance (PS32). Service quality (PS69).	PS32, PS34, PS39, PS54, PS55, PS62, PS69, PS75, PS77, PS78, PS80
Developers	Use of guidelines	Use accessibility guidelines appropriate to content, like WCAG, Section 508, AbleGamers Charity, Game Accessibility Guidelines (PS21, PS35, PS39, PS62, PS63, PS66, PS75, PS76, PS77). Integrate other features, such as usability (PS13, PS11, PS40, PS39, PS38, PS35, PS57), user experience (PS47), and privacy (PS25) within accessibility.	Awareness of accessibility (PS21, PS66), web accessibility integration (PS42), and promotion of legal accessibility requirements (PS39, PS42, PS75).	PS11, PS13, PS21, PS25, PS35, PS38, PS39, PS40, PS42, PS47, PS57, PS62, PS63 PS66, PS75, PS76, PS77
Developers	Practices for users' participation and promotion of needs	Involve users with disabilities and non-disabled users using methods like participatory design, user-sensitive inclusive design (PS13, PS62), or user-centered design (PS35). Also, communicate with users after publication (PS62).	Creation of engaging experiences (PS13), exploration of new possibilities (PS13) and ideas of realistic input and output methods and actual challenges (PS4, PS13), motivation of web developers to promote accessibility (PS35), and levels of perceived privacy and satisfaction (PS25).	PS4, PS13, PS35, PS25, PS62

Developers	Design for AT compatibility	Provide easy-to-use AT extensions and natural interaction (PS22, PS29). Consider suitability for the context (PS14). Involve users with disabilities and their caregivers in designing AT (PS1, PS14).	Technology acceptance (PS18) and autonomy (PS1).	PS1, PS14, PS18, PS22, PS29

4.1.1 Support to Web Development

Managerial support for developers is crucial to achieving accessible websites. This support should involve training in accessibility importance and knowledge across the development process, including practices, as this motivates web practitioners to give greater consideration to web accessibility (Shi, 2007; Vollenwyder et al., 2019). In addition, because identified accessibility problems may not be known to managers and developers, these individuals should study how to respond to these problems (Navarro-Galera, Alcaraz-Quiles, & Ortiz-Rodríguez, 2016). Therefore, training should also engage educators, information professionals, and those who train developers and managers (Henninger, 2017). Project managers, as well as web developers, mostly face accessibility and usability compliance issues related to the complexity of guidelines and a lack of knowledge on how to incorporate accessibility techniques into different stages of the development process (Lazar et al., 2004; Martins et al., 2017; Vollenwyder et al., 2019). Therefore, providing manuals for government agencies, for example, can help them ensure that websites are compliant with regulations (Olalere and Lazar, 2011). From a sociocultural perspective, these practices should also allow for the involvement of local practices and promote synergy with local non-interactive design practices, techniques, and processes (Sharp et al., 2020). It is notable that accessibility issues are often less technical or functional. From a design science research perspective, Iivari et al. (2020) suggest that accessibility is a criterion for artifact reusability, and should thus be reflected in the design principles of the artifact. These principles should be easy to understand, easy to comprehend, and intelligible (Iivari, Hansen, & Haj-Bolouri, 2020).

4.1.2 Evaluators' Level of Expertise

Whether or not the evaluator is a developer or an external evaluator, the management should consider the evaluator's level of accessibility expertise when recruiting to ensure the quality of measurements and to improve the validity and reliability of the results (Brajnik et al., 2011; Jaeger, 2006). Expertise can affect the quality of accessibility evaluation, especially in terms of validity and reliability (Brajnik et al., 2011). According to Lorca, Andrées, and Martínez (2012), big enterprises pay more attention to web accessibility, as they have high political costs and the resources to be more innovative and to hire experts. This finding suggests that accessibility requires resources. However, Yi (2015) suggests that there is no significant association between website accessibility and IT budget. This suggests that a lack of awareness of accessibility can present challenges.

4.1.3 Engagement of a Diverse Range of Stakeholders

In order to improve attitudes toward and commitment to promoting accessibility, managers should engage a diverse range of stakeholders, such as line managers, copywriters, policymakers, educators, and decision-makers, to make accessibility a reality (Henninger, 2017; Kennedy, Evans, & Thomas, 2011; Lazar et al., 2010; Wentz et al., 2014).

4.1.4 Accessibility Evaluation

To evaluate the level of accessibility, several studies suggest combining automated and manual evaluation procedures (Brajnik et al., 2011; Martins et al., 2017; Romano, 2002). Automated evaluation consists of automatic tools that can be used to screen websites effectively to identify accessibility errors violate design principles (e.g., WCAG and Section 508), recommendations, or other guidelines encoded in that tool (Brajnik et al., 2011; Martins et al., 2017). The evaluation should be conducted regularly to check ongoing accessibility compliance of new and updated posts on a website (Lazar et al., 2013). In order to assess the accessibility of the entire site accurately, the homepage and first-level pages should be evaluated for accessibility (Hackett & Parmanto, 2009).

As accessibility issues often require human intervention, manual assessment is still necessary (Brajnik et al., 2011). The manual evaluation procedure should involve a definition of the scope of evaluation, identification of evaluation tools, and a definition of the evaluation result format (Martins et al., 2017).

Manual evaluation may include several techniques, including inspection techniques, screening techniques, subjective assessments, and user testing (Brajnik et al., 2011). It is also necessary to evaluate perceived usability through a usability evaluation, such as a usability heuristics evaluation (Martins et al., 2017). Santana and Baranauskas (2015) propose a tool for investigating client-side event logs (usage data) of interactions that can be used to understand the characteristics of event streams related to AT and non-AT users. This technique may provide remote, informal, and asynchronous data due to the low effort required from participants and evaluators to identify barriers when AT users perform real tasks (Santana & Baranauskas, 2015). Matthew et al. (2020) propose a method for detecting arousal caused by frustration by measuring pupillary response and gaze behavior that can be used to complement other accessibility and usability testing methods. Frustration increases the level of arousal, and an increased level is a critical factor in performance and user experience (Matthews, Davies, Vigo, & Harper, 2020).

According to Brajnik et al. (2011), all these techniques differ in their generated results. Thus, the quality of the assessment method used can be considered in terms of the following: (1) effectiveness: how the method can help to identify all and only real problems; (2) usability: if the method is easy to understand, learn, and remember; (3) usefulness: the level of evaluation and how effectively the results reported by this method can be applied to practice; and (4) efficiency: the required resources for using this method. Overall, the evaluation of accessibility should be a higher priority in a general evaluation (Kamoun & Basel Almourad, 2014).

4.1.5 Use of Guidelines

The use of accessibility guidelines and practical design solutions to address the specific needs of people with disabilities is vital in the creation of an accessible website and to satisfy minimum legal requirements (Fagan & Fagan, 2004; Kamoun & Basel Almourad, 2014; Kuzma, 2010; Loiacono & McCoy, 2004; Parmanto & Zeng, 2005; Vollenwyder et al., 2019). However, if these guidelines are confusing, are hard to use, and do not cover the target group being addressed, they will likely be neglected, causing further accessibility problems (Brajnik et al., 2011; Kennedy et al., 2011; Lazar et al., 2004). Many scholars have criticized guidelines and argued that, despite the availability of existing accessibility guidelines, such as WCAG, most websites remain inaccessible (Brajnik et al., 2011; Giraud, Thérouanne, & Steiner, 2018; Lazar et al., 2004; Martins et al., 2017; Vollenwyder et al., 2019). Guidelines aim to improve accessibility from one perspective but do not necessarily consider other issues, such as privacy (Little, Briggs, & Coventry, 2005), usability (Giraud et al., 2018; King & Youngblood, 2016), or user experience (Aizpurua et al., 2015). For example, the UIs of systems used in public areas, such as ATMs, should be accessible. This might involve providing high-contrast and large text so that people may perceive the text on the screen easily while still considering strategies for preventing privacy violations (Little et al., 2005).

In some cases, web developers and web designers feel that implementing accessibility solutions will disturb their web design, as they treat their designed artifacts like pieces of art and make changes only if legislation forces them to do (Harper & Bechhofer, 2007; Lazar et al., 2004). However, some regulations only encourage designers to consider accessibility issues for people with disabilities, which means that the final decision regarding the implementation of accessibility features is made by designers (Kanayama, 2003). Nevertheless, the use of guidelines is crucial to making web content accessible and compliant with legal requirements, as well as to increasing awareness of web accessibility (Yi, 2015).

For example, Ruiz et al. (2011) implemented design for all principles in the context of a museum's multimedia guidance system to facilitate guide accessibility (Ruiz, Pajares, Utray, & Moreno, 2011). The authors provided an "accessibility mechanism" that allowed for the configuration and changing of resources to meet specific needs. For example, the guide soundtrack could be replaced with subtitling and signing windows, and images could be accompanied by an audio description, audio navigation, magnification, and a contrast modifier (Ruiz et al., 2011). Similarly, Santarosa et al. (2011) provided usability and accessibility design patterns for a full scope of implementation initiatives with the aim of reducing cognitive load and increasing autonomy for people with cognitional, sensorial, and physical needs, based on the following principles: (1) allow users to resize text, (2) label text alternatives for non-textual content, (3) allow keyboard access to all elements and functions with shortcut key orientation, (4) provide a consistent browsing mechanism, (5) place functionality in the same location and order, (6) help mechanisms provide situational sensitive content, (7) use sign language and audio in orientation, and (8) maximize compatibility with screen readers (Santarosa, Conforto, & Machado, 2014).

4.1.6 Practices for Users' Participation and Promotion of Needs

Many of the accessibility problems identified with automatic tools can be fixed relatively easily (N. E. Youngblood, 2014; S. A. Youngblood & Youngblood, 2018). However, while the use of accessibility guidelines in the design process is vital, the creation of an accessible website requires more than just compliance with existing guidelines or standards. In addition to confusing guidelines, developers also face problems such as lack of time and lack of support from the client (Lazar et al., 2004). If clients and users with a diverse range of abilities actively promote their needs and take part in the development process, accessibility (Jaeger, 2006; Vollenwyder et al., 2019) and levels of perceived privacy and satisfaction (Little et al., 2005) can become stronger. Vollenwyder et al. (2019) identify several beliefs that motivate developers to consider web accessibility: (1) involvement of users with a disability in the design process with a user-centered design method; (2) support of management through accessibility training across the development process, including practices that benefit web practitioners' "self-perceptions as a specialist," which motivates them to use their acquired knowledge in their professional capacity; and (3) acknowledgment of web accessibility by an organization as beneficial for improving the quality of the product (Vollenwyder et al., 2019).

Another major problem for developers is a lack of knowledge on how to incorporate accessibility techniques during the design process (Lazar et al., 2004). Often, developers either focus on users' limitations and compensate for these with viable solutions, or they concentrate on providing customization and alternatives in interaction patterns for existing content to prevent the impact of barriers (Martins et al., 2017). Scholars suggest involving users in the design process by using participatory design, user-sensitive inclusive design (Gerling et al., 2016), or user-centered design (Vollenwyder et al., 2019). Involving people with diverse needs and people with and without disabilities in the design process adds not only realistic perspectives regarding actual needs and challenges but also opportunities to identify new possibilities (Gerling et al., 2016; Jaeger, 2006; Seaborn et al., 2016). The involvement of users can be seen as crucial to creating engaging experiences or useful technology (Gerling et al., 2016). Moreover, communication channels should be kept open for continuous and iterative evaluation (Jaeger, 2006). Although user involvement in the design process is generally considered the most acceptable and respectful method for requirements elicitation, it also has challenges: participants' lack of experience participating in the design process, and there can be communication barriers (Gerling et al., 2016).

4.1.7 Design for AT Compatibility

AT is a means of equitable access for people with disabilities (Raisamo et al., 2019). The literature reviewed emphasizes the importance of understanding the functions and limits of AT and how users navigate IT artifacts with AT (Giraud et al., 2018; Pérez-Espinosa, Martínez-Miranda, Espinosa-Curiel, Rodríguez-Jacobo, & Avila-George, 2017). The studies reviewed primarily describe AT as an assistant that provides the inputs and outputs that a user may be lacking in an interaction (Loiacono, Djamasbi, & Kiryazov, 2013). The most widely adopted AT for digital information for individuals who are blind or visually impaired is the screen reader (Ferres, Lindgaard, Sumegi, & Tsuji, 2013). The use of read-aloud software also helps people with physical, cognitive, and literacy disabilities read an online text independently, while dictation software allows users to write text without unnecessary frustration with the keyboard, with both technologies improving user autonomy (Newman et al., 2017). Recent studies of screen readers have focused on issues with reading raw text from interface elements, such as text boxes, buttons, and menus, as well as on techniques that can interpret information from the different elements, such as graphs (Ferres et al., 2013) and simple shapes or images, through the use of haptics for people who cannot perceive visual information (Tekli, Issa, & Chbeir, 2018). Haptic assistance also improves interactions for people with motion impairments, for example, by reducing missed clicks during their interactions (Asque, Day, & Laycock, 2014). However, the use of an AT requires availability and the skills to use the technology, such as the ability to recall keyboard commands (Baldwin, Mankoff, Nardi, & Hayes, 2020).

Guerreiro et al. (2020) investigated smartphone-based virtual navigation apps that support independent navigation for blind people and could be used for learning routes and increasing prior knowledge of unfamiliar physical environments before a visit. They found that prior knowledge did not significantly improve users' performance; instead, users tended to rely on navigation systems in the moment (Guerreiro et al., 2020).

To ensure the acceptance of AT, we must make the interaction with AT as natural as possible (Pérez-Espinosa et al., 2017). For example, Pérez et al. (2019) propose a method that automatically recognizes paralinguistic elements from voice input (e.g., shouting, hyper-articulation, and hesitation) and can be used to personalize assistive content for a user (Pérez-Espinosa et al., 2017). Furthermore, Raisamo et al. (2019) propose future research directions for wearable interactive technology that enables human augmentation, including augmented senses, augmented action, and augmented cognition (Raisamo et al., 2019). These easy-to-use wearable extensions could support the full inclusion of people with disabilities by, for example, supporting their sensorial lack with augmented senses, as well as supporting an active lifestyle for the elderly (Raisamo et al., 2019). However, the cost of these novel technologies presents a problem for full adoption, as does suitability for individual users' needs, such as hearing impairment (Raisamo et al., 2019).

Another major factor that impacts the adoption of AT is its contextual suitability (Mäkelä & Vellonen, 2018). For example, in the context of special education, educators often have the best understanding of what is appropriate to match their pupils' needs and strengths, as well as what features AT should contain to promote active participation and thus match learning goals (Mäkelä & Vellonen, 2018). Therefore, designers need to consider the specific requirements of each context (Mäkelä & Vellonen, 2018) and involve both people with disabilities and their caregivers in the design process. Mentors with disabilities can identify difficulties experienced by others with disabilities and support growth in different areas of their lives, such as career, education, lifestyle, and social activity, to help them achieve higher levels of autonomy and develop their identity (Shpigelman, Weiss, & Reiter, 2009). According to Newman et al. (2017), the key barrier that arises in online social networking and digital inclusion of young people with disabilities, such as individuals with cerebral palsy, is their parents' lack of IT confidence. If parents are not aware of the available AT and social benefits that come from being online, they may not encourage their child to use IT without outside support (Newman et al., 2017).

4.2 Factors That Cause Accessibility Problems in Specific Population Groups and Proposed Solutions

To investigate the factors that cause accessibility problems for specific groups of people with disabilities, we used the ICF as a frame to categorize these groups. We used the ICF to compare which body functions and disabilities associated with specific groups were considered by the primary studies. From the primary studies, we identified factors relating to body functions and structures (ICF code (b)), including sensory functions and pain (b2) with sub-categories; seeing and related functions (ICF code b210-b229); hearing and vestibular functions (ICF code b230-b249); and neuromusculoskeletal and movement-related functions (b7). We then looked at activities and participation (d), including learning and applying knowledge (d1) and mobility (d4) (see appendix). In some cases, we were not able to identify the level and the type of disability to correspond to the ICF sub-codes, which we then addressed to the main domain. Table 4 presents the factors identified as causing accessibility barriers for specific groups of people with disabilities in IT artifact use. In the following subchapters, we describe the general characteristics of these groups and explain the identified factors in detail.

Table 4. Summary of the User Perspective Factors Causing Accessibility Problems in IT Artifact Use and Suggested Solutions by the Literature

ICF	Factors Causing Problems	Solutions Suggested by the Literature	ID
Seeing and related functions	Relevant content is far away.	Provision of extension that restructures relevant information first (PS6). Provision of summaries of the relevant content (PS12).	PS6, PS12
Seeing and related functions	The difference between primary and secondary menus expressed visually cannot be recognized.	Provision of a dual Interface (text-only) for blind users.	PS11
Seeing and related functions	Exploration of all repeated menu options on different pages takes too much time. Menu items can be learned after one recitation of all items.	Provision of a dual interface (text-only) for blind users (PS11). Provision of a link to skip navigation (PS19).	PS11, PS19
Seeing and related functions	Unnecessary visual content and application features.	Provision of extension that allows visual content to be removed (PS6). Provision of a system that automatically removes unnecessary features (PS50).	PS6, PS50

Seeing and related functions	Toggle menu not found.	Provision of extension that allows toggle menu to be set on and off.	PS6, PS12
Seeing and related functions	Visually presented information in graphs and figures are not perceivable. Text alternatives are missing.	Use of natural language to facilitate auditory processing (PS5, PS77). Provision of alternative texts, captions, mentions text labels, and metadata when information is presented in figures, graphs, and other image-related texts.	PS5, PS56, PS58, PS61, PS67, PS77, PS79, PS81
Seeing and related functions	Links without clear indication of their goal.	Provision of consistent link with the description of its purpose (Gist summaries) and described accessibility level of the link target.	PS12
Seeing and related functions	Input field in forms is missing.	Placement of input field right after question text.	PS3
Seeing and related functions	Design is unfamiliar.	Promotion of familiar design. Ensuring that the location of functionalities and their goal are recognized.	PS12
Seeing and related functions	Focus area and status in the forms and in the application are missing.	Provision of clear feedback regarding current status (PS3, PS50). Add voice awareness (PS74).	PS3, PS50, PS74
Seeing and related functions	Looping, dead-ending, or complex navigation.	Provision of directed linear paths (allowing for exploration) (PS12). Provision of simple navigation (PS72).	PS12, PS72
Hearing and vestibular functions	Difficulty comprehending or drafting accurate grammatical sentences.	The use of a bilingual approach.	PS43
Movement-related functions (PS30) Learning and applying knowledge (PS29, PS26)	Cannot hit the target in pointing interaction.	Provision of virtual cursors (PS30, PS29). No suggestion for an alternative, but it should not be replaced with special assistance (PS26). Provision of possibilities for horizontal screen mirroring and changing cursor behavior (Up-Down) (Left-Right) (PS74).	PS26, PS29, PS30, PS74
Learning and applying knowledge	Information retrieval difficult (accurate queries, word recognition).	Use of icons and words in a list structure with an array-like format.	PS23
Learning and applying knowledge	Remembering task-related steps.	Provision of wizards for the main functions or a level-structured design.	PS26
Learning and applying knowledge	Difficult terminology or jargon and long sentences.	Use of consistent terminology grounded in everyday life and short sentences.	PS26, PS72
Seeing and related functions (PS46) Learning and applying knowledge (PS23, PS7)	The format of the content does not support individual learning styles.	Provision of a combination of multiple outputs, such as audio, text, and images.	PS7, PS23, PS38, PS46, PS72

4.2.1 Seeing and Related Functions

Twenty of the primary studies focused on user groups that had visual disabilities or visual impairments. A "blind user" refers to an individual who cannot see any light (Loiacono et al., 2013) or visually presented information on a screen (Babu et al., 2010). Despite the existence of text-to-braille technology, many blind users and users with visual impairments prefer to use text-to-speech AT to interact with computers and voice commands with smartphones, which makes the interaction a listening and speaking activity (Babu et al., 2010; Dim, Kim, & Ren, 2018; Tesoriero, Gallud, Lozano, & Penichet, 2014). Compared to sighted users, blind users have a strong ability to encode verbal auditory sounds and identify individual sounds

(Baldwin et al., 2020). However, for sighted people, visual elements and non-audible content, such as text size, colors, and formatting, may convey meaning and provide cues about web page structure and intended navigation space, while blind users must form their mental model of the structure from linearly presented audible information of navigation items and other audible cues from the visual context (Leuthold et al., 2008). Text-to-speech AT, often called screen readers, reads a web page aloud from the top left to the bottom right (Babu et al., 2010). Thus, the navigation behavior of blind users is completely different from that of sighted users, which makes surfing the web extremely difficult for blind people (Harper & Bechhofer, 2007; Leuthold et al., 2008).

Baldwin et al. (2020) investigated nonvisual computing for blind and limited-vision users through an activity theory lens. They indicated challenges that users have with organizing their activities into specific tasks, realizing current operation status, and tracking web-surfing history, for example, when operating file management windows (Baldwin et al., 2020). The problem is that screen translation tools do not filter contextually irrelevant information from the processing stream. At the activity level, the system should not translate all open applications into audio space but only the application the user is focused on. At the application level, the system should recognize the current task and automatically remove unnecessary features (Baldwin et al., 2020). Distinctions between levels of activity should be made clear and systematic in the design, and the burden of file and application management should be transferred from the user to the system (Baldwin et al., 2020). Leuthold et al. (2008) present examples of problems that blind persons face when navigating graphical UIs. First, the difference between primary and secondary menus expressed visually cannot be recognized. Second, recurring menu options on different pages can be learned only after listening to all page menus. Third, the exploration of all menu options takes time. Strategies that sighted people may use when interpreting content, such as trial and error, do not work for blind people because they require too much effort (Leuthold et al., 2008). Poor web design forces the user to spend extra time and physical or mental effort addressing problems (Babu et al., 2010).

To address this issue, Leuthold et al. (2008) propose providing a dual UI with a text-only interface for blind people. Thus, blind people can advance without having to listen to the auditive substitute for the visual content elements (Leuthold et al., 2008). However, in practice, providing an alternative interface for people with disabilities does not conform to the terms of inclusion, as it separates people into different groups. Furthermore, developers are not eager to create separate semantic mark-ups or make any compromises to their design (Harper & Bechhofer, 2007). Therefore, it is important to deal with the gap between visually pleasing sites and visually impaired users who interact with these sites (Harper & Bechhofer, 2007). Giraud et al. (2018) propose filtering all redundant and irrelevant information that is not necessary for task completion from the layout to reduce cognitive overload. For example, if web pages containing redundant elements, such as logos, menus, and advertisements, are filtered after the first page, the user will not have to listen to all these elements again while navigating pages. This will reduce cognitive load and improve performance in three usability criteria: effectiveness, efficiency, and satisfaction (Giraud et al., 2018). In addition, Aizpurua et al. (2016) emphasize the importance of providing features for skipping navigation links, as well as careful consideration of information architecture, navigation menus, and text quality to provide better UX for blind users. To support inclusion in the learning context, Morrison et al. (2019) present a tool (physical programming) that enables an inclusive learning experience for children with mixed visual abilities together with sighted children, which provides the additional benefits of supporting friendship between these children.

Technologies embedded in smartphones, such as motion sensors, have enabled the development of 3D-space motion- and gesture-based marking menus (physical movement of the device in a certain direction to assign a selection) as an alternative navigation system to voice command, which can be insufficient in noisy environments or inappropriate in quiet public environments (Dim et al., 2018). Dim et al. (2018) propose an optimal number of menu items that could be adaptable for users with visual impairments. To reduce frustration with voice guiding and increase efficiency and comfort, Dim et al. (2018) recommend that users be able to customize their menu layout. They recommend that designers use four, six, or eight items in breadth and a maximum of two-level-deep menus (Dim et al., 2018). Harper and Bechhofer (2007) propose technical solutions that allow for the emergence of implicit structural-semantic information, as this can help users find and access information. The proposed provision of an extension gives particular characteristics (upper-level ontology) to specific cascading stylesheet elements. Users can (1) remove unnecessary visual information, such as banners and advertisements, to increase reading speed and cognition; (2) turn toggle menus on and off, as these menus are inaccessible to people with visual impairments; and (3) reorder the content by bringing important items to the top by using a “document level” feature in the XHTML structure (Harper & Bechhofer, 2007).

Other visual content, such as graphs, figures, and other image-related texts, are likely to remain inaccessible to blind people unless a tool is developed that compensates vision with another sensory modality, such as sound, touch, or a combination of these (Ferres et al., 2013; Shi, 2007). According to Ferres et al. (2013), previous research related to blind users' interpretation of visual information in graphs has proposed technical solutions using haptic interfaces, sonification, natural language interfaces, and hybrid interfaces to convey visual information using touch, sound, or both. By using a vibrating touchscreen, blind users can identify, recognize, manipulate, and map simple line shapes, geometric objects, graphics, and images; however, people with visual impairments are still keen to use natural language technology when interacting with these technologies (Ferres et al., 2013). Language modality has, therefore, been more successful than haptic or sonification solutions (Ferres et al., 2013), yet the more common strategy is still to use text alternatives, captions, mentions, text labels, and metadata to ensure that people with visual disabilities are able to perceive the same information presented visually (Hackett & Parmanto, 2005; Splendiani & Ribera, 2016; Youngblood & Youngblood, 2018; Yu & Parmanto, 2011). In addition, adding additional auditory feedback to icons and nearby elements can assist users with visual impairments by providing navigational information that enables users to create strategies for task completion (Barreto, Jacko, & Hugh, 2007). For these reasons, Ferres et al. (2013) propose using a natural language interface to facilitate auditory processing of visual elements, such as graphs.

Babu et al. (2010) reported four main issues that blind users face when interacting with online assessments, questionnaires, and interactive forms. First, blind users are prone to missing questions if the system does not provide clear feedback in the focus area and status. Second, the user's answer selection for a multiple-choice question does not indicate the action of the enter key in the checkbox area. This raises difficulties in comprehending the selection process for multiple-choice questions. Third, with essay-type questions, users may have difficulty finding the input field if it is not placed directly after the question text in the layout. Fourth, users may be expelled by the system if they use the backspace key to delete text from a text input field (Babu et al., 2010).

It is necessary to understand the behavior of blind users to identify problems in their interaction with web pages. Vigo and Harper (2013) identify and categorize several coping tactics that blind users employ when facing certain situations, such as situations of uncertainty, reduced mobility, confusion, and overload. People may experience uncertainty due to unfamiliar design grounds. To avoid this, it is essential to design for familiarity, or at least learnability, by promoting the user's understanding of the task flow and making sure that all functionalities of the interface, their location, and their goal are recognized. Navigation problems that allow users to get stuck in dead-end or looping navigation paths can be avoided by providing directed linear paths together, allowing users to explore off-shoots as well (Vigo & Harper, 2013). Situations of confusion were the most common type of challenging situation encountered by blind users. Confusion can arise when exploring the links that lacked a clear indication of the goal, such as a situation in which a user becomes confused by clicking a link and landing on an unexpected page (Vigo & Harper, 2013). This problem could be solved by avoiding ambiguity and providing consistent link text that describes the purpose and goal of the link, or by providing augmented techniques, such as Gist summaries of the link target page and its level of accessibility (Vigo & Harper, 2013). Factors like high information density and the presentational order of information may cause overload (Vigo & Harper, 2013). Providing relevant summaries of the content or applying techniques that enable users to highlight important information, remove irrelevant content, or clear cluttered content can help mitigate overload (Vigo & Harper, 2013).

4.2.2 Hearing and Vestibular Functions

According to Hammami et al. (2019), 5% of the global population has disabling hearing loss, which is about 466 million people worldwide, 34 million of whom are school-aged (WHO Newsroom, 2020). Despite this large number, our SLR revealed only one study that focused fully on the accessibility issues of people with disabling hearing loss. The World Federation of the Deaf (WFD) reports that 80% of deaf people lack education and are illiterate or semi-illiterate (Hammami et al., 2019). Learners with hearing impairments face difficulties in reading and writing, comprehending or drafting accurate grammatical sentences, and internalizing the core concepts of their educational coursework (Hammami et al., 2019). According to Hammami et al. (2019), the use of technology to provide adaptable learning environments to meet the educational requirements of deaf students is vital to achieving better learning outcomes. They propose an adaptable e-learning system in which students' learning achievements are monitored by identifying and specifying any weaknesses and then determining alternative activities with specific additions, such as conducting reading and questions in sign language and the students' official language to develop students' reading and writing skills (Hammami et al., 2019).

The majority of deaf individuals primarily use sign language to communicate. Their second language is usually the official language of their region. Deaf people usually communicate with manualism and oralism. Manualism is the communication of words and concepts through the use of the fingers. Oralism involves hearing training, high voice, and lip-reading for pedagogical purposes. New teaching methods, such as bilingual and bicultural methods, are being adopted to teach deaf students. To achieve lesson objectives in the learning context, Hammami et al. (2019) recommend concentrating on general objectives by indicating the core idea rather than the words themselves.

4.2.3 Neuromusculoskeletal and Movement-Related Functions

Four of the selected studies examined movement-related disabilities in people with motor impairments (MI). People with MI may have difficulties using standard pointing and input devices, such as mice and keyboards, to interact with computers (Almanji, Claire Davies, & Susan Stott, 2014; Pérez, Valencia, Arrue, & Abascal, 2019), and communicating and accessing education tools due to the limited dexterity of their upper limbs (Pérez et al., 2019). Individuals with MI may also have difficulty using a computer due to poor coordination, slow movements, low strength, tremors, spams, rapid fatigue, or difficulty controlling direction or distance (Pérez et al., 2019). Various AT have been developed to facilitate these needs (Almanji et al., 2014; Pérez et al., 2019). Parallel symptoms are also caused by some diseases, such as cerebral palsy, spinal cord injury, multiple sclerosis, muscular dystrophy, Parkinson's disease, arthritis, or missing limbs and digits (Pérez et al., 2019).

Further studies need to be conducted to develop a deeper understanding of how to design accessible IT artifacts to assist people with movement-related disabilities (Almanji et al., 2014). A few studies have recognized the pointing and clicking interaction (e.g., targeting and clicking a dropdown menu or other small element on a web page) as difficult for people with MI. To strengthen IT artifact interaction for people with MI, Pérez et al. (2019) recommend providing virtual cursors, like cross cursors, that highlight the mouse cursor area with a light-colored full-page cross to assist perception when pointing and clicking. An accurate understanding of the user's physical ability to use a pointing device (i.e., a mouse) is needed. The ability to use pointing devices could be measured, for example, by movement time, acceleration, average speed, or distance traveled (Almanji et al., 2014; Lin, Breugelmans, Iversen, & Schmidt, 2017; Pérez et al., 2019). Movement time is the greatest predictor of ability (Almanji et al., 2014). Furthermore, mobile device applications should be designed so that they can be used by both hands, as people do not always have the same skills or abilities in both hands (Tesoriero et al., 2014). An accurate understanding of a user's ability to move their limbs, including their finger movements, enables designers to build systems with adaptive interfaces where the system can recognize what physical control the user is using and automatically calibrate different adaptions to different individuals (Lin et al., 2017).

4.2.4 Learning and Applying Knowledge

We identified nine studies that addressed issues relating to learning and applying knowledge. Cognitive disabilities that affect the application of knowledge, learning, thinking, problem solving, and decision making (WHO, 2013) are often considered together, but individuals have different patterns of cognitive deficits. It is, therefore, necessary to consider each specific cognitive deficit when analyzing its role in interaction (Sevilla, Herrera, Martínez, & Alcantud, 2007). For example, dyslexia is a common learning disability that occurs in 3–10% of the population (Berget, Mulvey, & Sandnes, 2016). Dyslexia is treated as a permanent disability that affects word recognition, decoding, and spelling in various forms and degrees (Berget et al., 2016). Between 18% and 20% of the dyslexic population have dual diagnoses of other specific learning disabilities, such as attention deficit hyperactivity disorder (ADHD) or attention deficit disorder (ADD) (Berget et al., 2016). Dyslexia is usually discussed in learning contexts (Alghabban, Salama, & Altalhi, 2017; Berget et al., 2016). Alghabban et al. (2016) and Kennedy, Evans, and Thomas (2011) recommend providing a combination of multiple outputs, such as audio, text, and images, in learning materials to allow students to interact with the content according to their learning style. It has been argued that content with multimodal interactions, such as the use of voice to narrate pages, can remove barriers for people with cognitive disabilities (Alghabban et al., 2017; Berget et al., 2016; Kennedy et al., 2011; Sevilla et al., 2007). For example, providing icons and words in a list structure benefits both dyslexic and non-dyslexic users (Berget et al., 2016). However, other studies contradict these findings. Some scholars claim that visual content can accommodate users with reading impairments, while others argue that pictures may distract users from the text, negatively affecting reading comprehension (Berget et al., 2016). According to Dyson and Haselgrove (2001), many accessibility studies concentrate on identifying factors that can improve reading performance and support effective reading, such as the use of sans-serif font types, large font sizes, increased letter spacing, and reduced line length (medium 55 characters per line). Beyond this, research should focus more on the barriers that dyslexic individuals and people with intellectual disabilities self-report, such as website navigation or information retrieval, that require accurate queries and word recognition skills (Berget et al., 2016; Kennedy et al., 2011).

Aging and its relationship to the development of cognitive disabilities, such as changes in sensory, motor, and cognitive abilities (Pérez-Espinosa et al., 2017), is a relevant topic, since the populations of many countries are reportedly aging. Sayago and Blat (2010) argue that factors that cause cognitive difficulties, such as cognitive load, remembering task-related steps, understanding terminology, or using a mouse, are more relevant to older people than difficulties like reading from the screen or perceiving other visual information, like icons. Aging is also a cognitive factor that influences cognitive mapping, which is a crucial component of wayfinding ability that people use to recall and understand the environment and navigate through it (Sharlin et al., 2009). To reduce cognitive load, designers should avoid using long sentences, difficult terminology or jargon in the text content of an IT artifact, as this may significantly increase older people's motivation to use information and communication technology (Kennedy et al., 2011; Sayago & Blat, 2010). Autonomy and inclusion are key factors that improve older people's motivation to use information and communication (Sayago & Blat, 2010). Autonomy means that individuals with disabilities do not need to rely on others when using the system, and inclusion means that they do not feel different or like they need special assistance (Sayago & Blat, 2010).

4.2.5 Mobility

We identified four studies on accessibility issues related to mobility. One study discussed the information-use behavior of people with physical disabilities (Liang, Xue, & Zhang, 2017), two discussed game design (Gerling et al., 2016; Seaborn et al., 2016), and one discussed AT acceptance (Barbosa, Tavares, Cardoso, Alves, & Martini, 2018). The ICF defines mobility as moving by changing body position or location or by transferring from one place to another; by carrying, moving, or manipulating objects; by walking, running, or climbing; and by using various forms of transportation (WHO, 2013).

According to Liang et al. (2017), level of disability affects how a user perceives information quality and system quality. Information quality and system quality are predictors of perceived benefits and perceived risk of using information, such as online health information. Liang et al. (2017) argue that people with a higher level of disability perceive risk as having no significant difference if the information quality is low or high; however, if the system quality is high, it has a strong positive effect on the perceived risk, which can be dangerous because fake websites, for example, can give the impression of having high system quality, which users rely on to assess risk.

Seaborn et al. (2016) identify user generated themes that should be considered in a mixed-reality game designed for people with mobile impairments. These themes contain factors, such as the inclusion of people with various skills and abilities, players on foot, opportunity to socialize with new people, opportunities to select a role that balances skill and ability fairly, challenges, accessibility, and easy-to-use equipment and UI (Seaborn et al., 2016). According to Gerling et al. (2016), the involvement of people in wheelchairs and non-disabled people in the design of games with participatory designs is crucial to designing an engaging experience that is realistic regarding disability, has the concept of play, and is technically feasible. Barbosa et al. (2018) investigated how wheelchair users might be assisted by providing context-aware assistance based on location information produced by ubiquitous technology integrated into a wheelchair and how this technology is accepted. This type of inclusively designed AT can provide positive social opportunities and autonomy for people with disabilities (Barbosa et al., 2018).

5 Synthesizing Research Findings

We identified management- and development-level factors that affect accessibility and possible solutions suggested in the literature (Table 3). We also identified factors that cause accessibility barriers for users and solutions for these (Table 4). To develop an understanding of the key factors and actions between domains, we interpreted the results and synthesized what needs to be addressed to achieve accessible IT artifacts. As shown in Figure 1, we identified four domains, the factors within them, and their roles and actions that influence the realization of accessibility. The domains are (1) user, (2) management (3) developers, and (4) features of IT artifact. We identified relationships between these domains, which include interaction loops. These interaction loops are illustrated as an arrow (Arrow a-g) in Figure 1. The relationships include (1) the interaction between user and IT artifact features, (2) the interaction between user and developers, (3) the interaction between developers and management, and (4) the interaction between developers and IT artifact. In the following sub-sections, we discuss the key factors by domain, how they should be addressed, and what are the essential interactions between them.

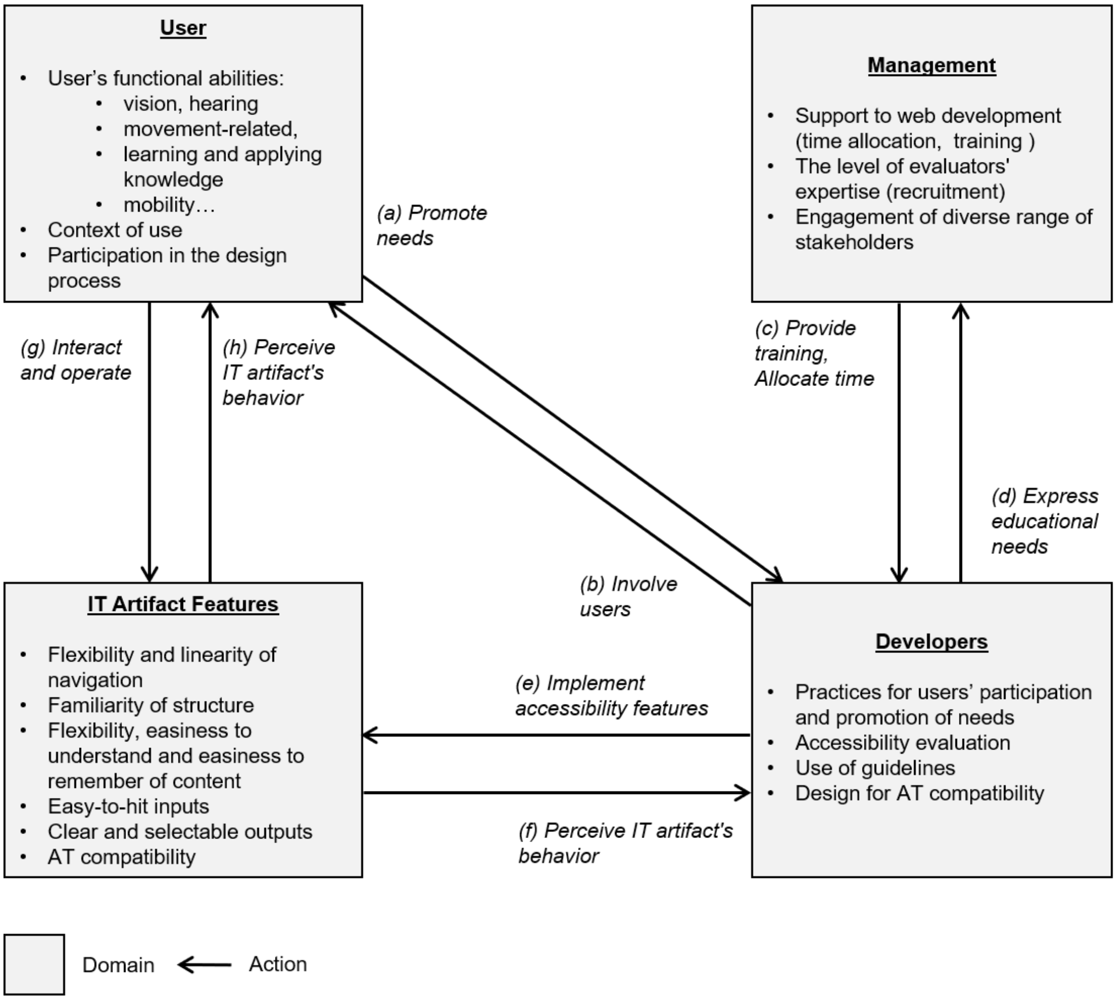

Figure 1. Key Factors and Solutions Affecting Accessibility

5.1 User

In the user domain, four factors related to the *user's functional abilities* affect a user's interaction with an IT artifact, including their sensory ability (e.g., seeing and hearing), movement-related ability, ability to learn and apply knowledge (cognitive), and ability for mobility. Information about the *context of use* and *participation in the design process* are two additional factors that influence developers' knowledge. Therefore, research-based knowledge of users' abilities (see Section 4.2) and *users' promotion of their actual needs* (Arrow a) through participation in design and evaluation processes are crucial to expanding developers' knowledge of accessibility issues and motivation to promote accessibility and to explore new opportunities of experience. During participation, *users interact and operate* (Arrow g) with an IT artifact in development and *perceive the IT artifact's behavior* (Arrow h), thereby increasing their awareness of their own needs for IT artifact features. These needs should involve the factors that the interaction with an AT raises and information about the users' context (Mäkelä & Vellonen, 2018; Santana & Baranauskas, 2015). These need should be communicated to developers. Depending on the participant's level of disability, their caregivers should also be invited to participate to ensure thorough information gathering (Mäkelä & Vellonen, 2018; Newman et al., 2017). Detailed descriptions of the factors related to accessibility barriers for each group and proposed solutions suggested by the primary studies have been described previously in Section 4.2.

5.2 IT Artifact Features

We reviewed studies that explored accessibility barriers for particular groups of people and made suggestions as to how to design and implement accessibility in IT artifact features to break down these barriers. Our synthesis identified six key factors related to IT artifact features. As these factors describe IT artifact features, they can be considered suitable solutions to improve accessibility. These factors include *flexibility and linearity of navigation*; *familiarity of structure*; *flexibility, ease of understanding*, *and ease of remembering content*; *ease-to-hit inputs*; *clear and selectable outputs*; and *AT compatibility*.

Accessibility issues relating to navigation often present barriers for users with seeing and related disabilities. Our results reveal that accessible navigation should be flexible and straightforward. The navigation should provide one mechanism (Leuthold et al., 2008) that is as linear as possible, allowing for exploration (Vigo & Harper, 2013); should allow the user to skip navigation (Aizpurua et al., 2016); should be modifiable (Harper & Bechhofer, 2007; Vigo & Harper, 2013); and should provide information about links with informative names (Aizpurua et al., 2016).

An accessible structure should also be familiar (Vigo & Harper, 2013). Its elements should be in consistent locations, and the goal of its functionalities clearly indicated (Babu et al., 2010; Vigo & Harper, 2013).

Poor accessibility of content affects the interaction of users with visual, auditory, and cognitive disabilities. To improve accessibility, the content should be flexible, easy to understand, and easy to remember. Flexibility means that IT artifacts should contain functions or extensions that allow users to remove visual content and reorganize relevant content to appear first (Baldwin et al., 2020; Harper & Bechhofer, 2007), or the relevant content should be designed so as to appear first (Vigo & Harper, 2013). All visually presented information (e.g., graphs) should also be presented as natural language so that screen readers can read these (Ferres et al., 2013; Hackett & Parmanto, 2005; Splendiani & Ribera, 2016). Easy to understand means that the text content should be presented with consistent and everyday terminology and with a bilingual approach (Hammami et al., 2019; Sayago & Blat, 2010). List structures should be presented with icons to improve word recognition (Berget et al., 2016). Easy to remember means that the exploration of the content should be guided with task-related steps, or tasks should be designed on a level structure (Sayago & Blat, 2010).

Interaction with pointing devices may present a barrier for users with movement-related or cognitive disabilities. An IT artifact should help users to hit the target with a pointing device (e.g., mouse) by providing virtual cursor assistance to indicate the cursor area (Almanji et al., 2014; Pérez-Espinosa et al., 2017). This technique should be implemented not as special assistance but as a regular feature so that individuals do not feel that their need for special assistance weakens their feeling of inclusion (Sayago & Blat, 2010).

If IT artifact outputs are based on only one format, this may cause barriers for people with visual or cognitive disabilities. Thus, IT artifacts should contain multiple modalities in output formats, such as text, audio, and images, so as to share information that is selectable by the user (Alghabban et al., 2017; Berget et al., 2016; Ruiz et al., 2011; Sevilla et al., 2007). The focus area should be indicated with clear feedback (Babu et al., 2010; Baldwin et al., 2020).

5.3 Management

Management-related key factors and solutions in IT development projects relate to the *support of web development*, including *training and time allocation* (Arrow c) for the project (Lazar et al., 2004; Martins et al., 2017; Sharp et al., 2020; Vollenwyder et al., 2019) and *recruitment of end-users*, and the utilization of designers' knowledge and expertise of accessibility issues, motivating them to conform to users' needs (Gerling et al., 2016; Little et al., 2005; Seaborn et al., 2016; Vollenwyder et al., 2019). Also, *the level of evaluators' expertise* should be considered when recruiting expert evaluators (Brajnik et al., 2011). To ensure a continuum of product accessibility, management should *engage a diverse range of stakeholders* to promote accessibility.

5.4 Developers

Developer-related key factors and solutions relate to *practices for users' participation and promotion of needs.* User requirement elicitation is the one step of IT artifact design process in which designers extract information from the users and other resources to provide design implications that comply with users' needs. *Involving users* (Arrow b) in promoting their needs is a key factor in understanding users' actual needs. User–developer collaboration should involve requirement elicitation, design evaluation, user tests, and so forth, using methods like participatory design, user-sensitive inclusive design, and user-centered design (Gerling et al., 2016; Little et al., 2005; Seaborn et al., 2016; Vollenwyder et al., 2019). The studies reviewed did not specify how many users and from which group of population should be involved in the development process.

An *accessibility evaluation* should be conducted using automated evaluation against principles and manual evaluation (Brajnik et al., 2011; Martins et al., 2017; Santana & Baranauskas, 2015). To confirm a certain level of accessibility, *the use of accessibility guidelines* (e.g., WCAG) and standards are vital but often insufficient alone (Cairns, Power, Barlet, & Haynes, 2019; Martins et al., 2017; Vollenwyder et al., 2019). The integration of other features, like usability, user experience, and privacy, is needed for the final design solution (Aizpurua et al., 2015; Gerling et al., 2016; Leuthold et al., 2008; Link, Armsby, Hubal, & Guinn, 2006; Little et al., 2005; Martins et al., 2017; Ruiz et al., 2011; Vollenwyder et al., 2019). When *designing for AT compatibility*, natural interaction, integration of easy-to-use AT extensions, and appropriateness given the context should be designed and validated with users (Mäkelä & Vellonen, 2018; Newman et al., 2017; Pérez et al., 2019; Pérez-Espinosa et al., 2017; Raisamo et al., 2019). If knowledge of these methods and techniques is lacking, it should be *expressed to the management* (Arrow d). During the design process and testing, developers must *implement accessibility features* into the IT artifact (Arrow e) and *perceive the IT artifact's behavior* (Arrow f).

6 Discussion

This SLR aimed to explore the factors related to accessibility barriers that should be considered when designing an accessible IT artifact as well as the solutions to accessibility barriers posed by the extant literature. These factors are presented as micro-level factors that have an impact on individual perceptions of accessibility, and management and development-level factors related to the IT artifact design project management and development processes.

This review adds to the body of knowledge by identifying the factors that present barriers to the accessible use of IT artifacts and by categorizing IT artifact features where these barriers occur. This review also identifies factors that affect accessibility and should be considered in IT artifact development. The AIS "basket of eight," tier-2 IS journals, and AIS-recommended top HCI journals reviewed did not produce any SLR studies on the same topic within the study timeframe. We found that literature reviews on accessibility factors and solutions are infrequent, especially in the IS discipline.

Other accessibility-related SLRs, such as the studies by Paiva et al. (2021) and Mack et al. (2021), present methods and tools that researchers have suggested could be used to incorporate accessibility into different phases of software development. Their findings also indicate that studies lack user group representation, including hearing impaired and cognitively disabled groups. The SLRs carried out by Ordoñez et al. (2020); Campoverde-Molina et al. (2020); and Zhang et al. (2020) found that most articles on the topic suggest using the WCAG to improve accessibility. However, the findings of the present study reveal that using only the WCAG is not enough to create accessible IT artifacts. This claim is supported also by Petrie et al. (2003) and Vigo and Harper (2013), who suggest that only about half of the accessibility issues encountered by blind people are covered in the WCAG.

Compared to previous studies, this study presents accessibility barriers that users with different abilities may face during their interaction with IT artifacts. This study has described design solutions that address these critical barriers and give users the opportunity to better use IT artifacts. After this critical point (when the user is able to use the IT artifact), we must question how the user perceives other features, such as usability, privacy, and good user experience. Many definitions of accessibility in the literature emphasize the importance of including usability in accessibility (Petrie, Savva, & Power, 2015); however, only a few studies have investigated this integration. Martins et al. (2017) provide a full scope of evaluation, which inspects accessibility and usability separately. Aizpurua et al. (2016) suggest a significant connection between how perceived web accessibility correlates with user experience features. Santarosa et al. (2011) provide a combination of accessibility and usability design patterns, which improve the perception of both of these features for deaf users, blind and low-vision users, users with reduced mobility, and users with attention deficit disorders and intellectual disabilities. Therefore, we agree that accessibility, usability, user experience, and privacy are all important considerations, but in light of our findings, we feel that accessibility and usability should be discussed in the research as unique features, as defined by the ISO standard and WCAG (International Organization for Standardization, 2018). In practice, this will improve the performance of both features because, if we were to combine these two features, it might confuse the evaluation, focus of the design, and focus of the development process, including training of the practices, which may result in overlap and some factors being missed. For example, instead of efficiency, accessibility describes the extent of autonomy (Ferres et al., 2013). More research is needed to clarify the methods and techniques for integrating these two features into one solution.

As a contribution to practice, we identified three qualities that together create a goal for accessibility. These qualities include users' perceived autonomy, perceived system quality, and perceived information quality. The goal describes the user's state of use and should be the goal of developing more accessible features. Accessibility is the extent to which users can interact and operate (using their perception, cognition, and action) (Babu et al., 2010; Gerlach & Kuo, 1991) a system successfully without external assistance. Therefore, one quality of accessibility is autonomy (Barbosa et al., 2018; Ferres et al., 2013; Newman et al., 2017; Santarosa et al., 2014; Sayago & Blat, 2010; Shpigelman et al., 2009). According to Ferres et al. (2013), autonomy is even more important than efficiency for certain people, such as those with seeing and related disabilities. Autonomy also influences motivation to use IT artifact in the future (Sayago & Blat, 2010).

Perceived system quality is a multidimensional quality, but from an accessibility perspective, accessibility itself is the strongest predictor of system quality (Liang et al., 2017). Other factors of system quality, such as fastness, navigability, and readability of the content (Liang et al., 2017), can be improved through accessibility features. For example, fastness can be improved by reducing cognitive load and improving remembering. Navigability can be improved through several accessibility factors related to navigation. The readability of content can be improved using a bilingual approach and by addressing the factors related to information architecture. Similarly, information quality can be improved by implementing accessibility features. Accessibility features themselves improve information perception. For example, intrinsic, contextual, accuracy, and completeness (Alkhattabi, Neagu, & Cullen, 2011), can be improved by context-sensitive design and by addressing the factors related to information architecture.

Information quality and system quality are both beneficial for value creation (Li & Shang, 2020). Information quality increases people with physical disabilities' perception of benefits, while system quality decreases their perceived risk (Liang et al., 2017). These two qualities have a positive effect on use behavior (Liang et al., 2017).

In sum, in order to achieve accessible IT artifacts (considering perceived autonomy, perceived system quality, and perceived information quality), management and developers need to follow the suggestions presented in Table 3. The user perspective factors identified as causing accessibility problems and the proposed solutions to these issues (presented in Table 4) should be addressed when designing IT artifact features. Lastly, the key factors and solutions, including actions between domains, presented in Figure 1 should be addressed.

Our study identified accessibility research themes related to the following issues that we recommend for further research in the IS and HCI disciplines:

(1) **Text content accessibility:** Our results reveal several suggestions for designing accessible content (e.g., locating relevant content first, using a bilingual approach, using everyday terminology). What guidelines can support content creators in producing accessible text that is beneficial for people with various disabilities, not just people with learning difficulties? It is noteworthy that text is still the primary form of information sharing on the web (Kalender et al., 2018), which makes reading the primary form of content interaction (Rello, Pielot, & Marcos, 2016).

(2) **Users with communication disabilities:** As interaction with IT artifacts often requires communication using language, signs, and symbols, including receiving and producing messages and carrying on a conversation (WHO, n.d.), IT developers need to consider possible barriers. What factors influence accessibility for users with communication disabilities?

(3) **Human augmentation and social acceptance of AT:** AT is often discussed in accessibility studies as it can augment users' abilities (Raisamo et al., 2019). Screen readers are a mainstream

AT that are crucial for some and benefit many users, including blind and visually impaired users and users with learning difficulties. Yet few studies have investigated the use of AT to assist users' thinking (e.g., cognitive matters) or communication. Furthermore, the use and acceptance of AT depend on how users perceive social acceptance, which influences their decision to apply these technologies. How does social acceptance influence AT acceptance?

(4) **Universal accessibility:** As stated before, the universality of accessibility solutions is rarely discussed in the literature. We see that the causalities between different features, such as accessibility and usability, are still underrepresented. Therefore, we suggest that IS and HCI research continue to examine how these two features and their design patterns affect one another. Further research should also look at how users with different levels of ability perceive these features. In addition, research should investigate how these design patterns can be integrated into one design solution.

This study, however, has its limitations. First, we based our SLR on the selected list of journals recommended by AIS and ranked by the Chartered Association of Business Schools. This scope may create some biases because the database is restricted to certain journals. We, however, identified 82 primary studies relevant to our research question which enabled us to achieve our research goals. Therefore, we believe we had a good sample that represented top and tier-2 IS research and top HCI research. Then, we used the search term "accessibility" solely. This may exclude some papers that used other similar terms. We expected that studies focused on accessibility do use this term in the paper. Third, the authors may have misinterpreted the results of primary studies in the data extraction phase. To avoid this, every step of exclusion was conducted by at least two authors to ensure the reduction of biases.

7 Conclusion

This paper presented a SLR of articles published in the top IS and HCI journals recommended by the AIS, and tier-2 IS journals ranked by the Chartered Association of Business Schools. Our findings produced a set of factors that affect accessibility in the development of IT artifacts and solutions to tackle these. We then listed the factors that led to accessibility barriers from the perspective of the user, and solutions to tackle these. We based user abilities on the ICF. Finally, we synthesized and illustrated factors and solutions related to accessibility.

Based on the results presented in this paper, a user's functional abilities—including sensory abilities, such as seeing and hearing; movement-related abilities; cognitive abilities, including the ability to learn and apply knowledge; communication abilities; and mobility—set certain design requirements for the features of an IT artifact. Some of these requirements address more than one ability. The elements of an IT artifact that feature these requirements relate to navigation, structure, content, input method, and output method. Specifically, navigation must be flexible and straightforward, the structure must be familiar, the content must be flexible and easy to understand and remember, the inputs must be easy to hit, and the outputs must be selectable and provide clear feedback.

Regarding the development of an IT artifact, managers, developers, and users play an important role in promoting accessibility. In the management domain, project managers influence accessibility knowledge by providing education and training for developers, recruiting experts to evaluate accessibility, and allocating time resources to the project. In the development domain, we identified factors that affect accessibility conformance. We found that users with disabilities, their caregivers, and non-disabled users should be involved in the design, testing, and evaluation processes to promote their actual needs. The compatibility of accessibility guidelines is vital to gaining a certain level of accessibility and complying with legal requirements but should not be used as the only method. Techniques for applying these guidelines should be considered in training. Evaluation should combine automated tools to identify accessibility errors that violate accessibility guidelines and manual evaluation procedures, including user testing and event logs. Other features, such as usability, user experience, and privacy, should be considered and integrated into the design so that they do not violate each other. The compatibility of AT should be considered in the design or integrated into the IT artifact as an extension. The AT should be designed with collaboration from users with disabilities and their caregivers to ensure suitability to the context. The IT artifact's suitability to the context should be considered in a context-sensitive design. Finally, we identified three qualities that that together create a goal for accessibility: perceived autonomy, perceived system quality, and perceived information quality.

These results provide future research directions for developing knowledge on accessibility. First, people with communication disabilities could be a target group for future studies, as they are a less studied group. Second, few studies have focused on how to produce accessible text not just for dyslexic individuals but also for those with other disabilities. We identified several design patterns to create accessible content, but future studies could extend this line of research. Third, studies on AT have have focused on the provision of augmented access, including input and output methods, but assistance for cognitive matters and the perceived social acceptance of these technologies have received less attention. We believe that gaining an understanding of needs in these proposed areas and integrating these needs into IT artifact design will be a step toward universal accessibility.

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Appendix: List of Primary Studies by ICF Category

ICF Domain Codes: Body functions and structures (b); Activities and participation (d)

ICF Sub-Domain Codes: Seeing and related functions (b210-b229); Hearing and vestibular functions (b230-b249); Neuromusculoskeletal and movement-related functions (b7); Learning and applying knowledge (d1); Mobility (d4).

ID	Paper	Specific Research Focus and Study Participants	Summary of Findings
ICF Domain Code: Body functions and structures (b) **ICF Sub-Domain Code:** Seeing and related functions (b210-b229)			
PS3	(Babu et al., 2010)	Blind users' web accessibility and usability problems, 6 participants with blindness	Blind users encounter the following problems with forms and questionnaires: susceptibility of skipping a question; inability to comprehend the process of answering multiple-option questions; ambiguity about responding to short-answer questions; threat of losing the assessment.
PS5	(Ferres et al., 2013)	Evaluation of a tool that improve access to charts and graphs, 10 participants with blindness and 10 sighted	"People with visual impairments can interact with natural language interfaces accurately to answer relatively complex questions about simple line graphs."
PS6	(Harper & Bechhofer, 2007)	Semantic web, persons with visual impairment	Semantic information encoded in documents can help users to understand visually presented information.
PS11	(Leuthold et al., 2008)	Design of text UIs, 39 participants with blindness	With text user interface, users can perform tasks faster with fewer mistakes.
PS12	(Vigo & Harper, 2013)	Coping tactics on the web, 19 participants with visual impairment or blindness	Coping in the web occurs in situations of uncertainty, reduced mobility, confusion, and overload.
PS15	(Dim et al., 2018)	Motion marking menu UI in smartphones, 12 participants with visual impairment or blindness	Participants can perform menu selections using marking menus faster than when using a touch-based menu.
PS16	(Lahib, Tekli, & Issa, 2018)	Vibrating touchscreens, 29 participants (6 blind since birth, 7 blind after birth, 16 sighted persons)	Fitts' Law can be applied to evaluate blind candidates using the vibration modality on a touchscreen and varying target sizes and distances on the touchscreen.
PS17	(Tekli et al., 2018)	Vibrating touchscreens for shapes and graphs, 29 participants with blindness or blindfolded	Participants are capable of accessing simple shapes and graphics presented on a vibrating touchscreen. However, issues, such as prolonged time, remain.
PS19	(Aizpurua et al., 2016)	Web accessibility correlation to UX, 11 participants with blindness	Web accessibility is correlated with UX.
PS20	(E. T. Loiacono et al., 2013)	Factors affecting user acceptance in a website, 59 participants with visual impairment	Reliability and convenience of access to information in websites should be considered in acceptance models.
PS24	(Bicakci & Kiziloz, 2016)	Human interaction proofs, 372 participants (203 normal vision, 162 "corrected to normal," 3 partially sighted, 2 with blindness)	Pure text-based human interaction proofs are more enjoyable than visual human interaction proofs.
PS31	(Giraud et al., 2018)	The effect of redundant and irrelevant information on a website, 76 participants with blindness	Filtering redundant and irrelevant information on a website reduces cognitive load.
PS33	(Morrison et al., 2019)	Computational learning with physical programming, 30 teachers and 75 children with vision impairment, blindness, or learning and physical disability	Children can learn computation successfully using physical programming.
* PS37	(Santarosa et al., 2014)	Universal design, Persons with visual or hearing impairment, or users with reduced mobility	UIs and tools with universal design address the user's cognitive, sensorial, and physical specificity intending to minimize cognitive load and develop more autonomy for people.

PS44	(Barreto et al., 2007)	Spatial auditory feedback in computer use, 10 volunteer with visual impairment	"Spatialization of icon sounds provides additional remote navigational information to users, enabling new strategies for task completion."
PS47	(Aizpurua et al., 2015)	The influence of prior experience to accessibility, 11 participants with blindness	Past experience affects the way in which users perceive and experience accessibility and UX.
PS50	(Baldwin et al., 2020)	Computing, 11 students with vision impairment or blindness	Changes between active windows and the status of operations at the application level should be designed with systematic distinctions between activity levels to reduce struggling in computing.
PS51	(Guerreiro et al., 2020)	Virtual navigation, 14 participants with blindness	Participants rely on their navigation system rather than virtually learned navigation routes before navigating in the real world, even if the system advances their prior knowledge of the environment.
PS62	(Jaeger, 2006)	U.S. governmental webpages, multi-methodological evaluation included 10 participants with visual or mobility impairments	Lacks the compliance with Section 508. Suggestions: design for accessibility, involve users with disability in testing, have accessibility experts in development team, use automated testing tools, have open communication channels, test accessibility on iterative basis, focus on accessibility for all users.
PS74	(Tesoriero et al., 2014)	Perception of the selection and environment on the screen	Voice awareness; operations should be usable with both hands; possibilities to adjust the font size.
ICF Domain Code: Body functions and structures (b) **ICF Sub-Domain Code:** Hearing and vestibular functions (b230-b249)			
* PS37	(Santarosa et al., 2014)	Multiple foci. See previous description.	
PS43	(Hammami et al., 2019)	Adaptive learning systems, Students with hearing impairment	An adaptive learning system improves students' reading and writing skills.
ICF Domain Code: Body functions and structures (b) **ICF Sub-Domain Code:** Neuromusculoskeletal and movement-related functions (b7)			
PS9	(Lin et al., 2017)	Adaptive interface design, Physical disabilities, particularly arthritis (in the hand)	Comprising eye-tracking and data glove technologies, user's physical ability can be translated to computer controls that utilize the user's abilities rather than focusing on disability.
PS10	(Asque et al., 2014)	Haptic assistance, 6 participants with different degrees of motion-impairment	Deformable haptic cones and deformable virtual switches reduce missed clicks and targeting time.
PS18	(Pérez et al., 2019)	Virtual cursors, 15 participants (9 with motor impairments and 6 without disability)	Virtual cursors improved the effectiveness and efficiency of most participants in link selection.
PS30	(Almanji et al., 2014)	Effects of impairment severity on cursor control, 29 participants with bilateral cerebral palsy	Movement time, acceleration–deceleration cycles, and average speed are used to assess different MACS (Manual Ability Classification System) levels.
* PS74	(Tesoriero et al., 2014)	Multiple foci. See previous description.	
ICF Domain Code: Activities and participation (d) **ICF Sub-Domain Code:** Learning and applying knowledge (d1)			
PS7	(Sevilla et al., 2007)	Web accessibility, 20 participants with a cognitive disability	"Equivalent but alternative content is a good model for people with cognitive disabilities."
PS8	(Sharlin et al., 2009)	A tangible user interface for assessing cognitive mapping ability, 20 participants	The use of tangible UIs for assessing cognitive mapping ability can improve flexibility, accessibility, sensitivity, and control.
* PS13	(Gerling et al., 2016)	Participatory design, 9 young wheelchair users with cognitive disabilities and 22 undergraduate students	The involvement of both groups is crucial for creating engagement, technical feasibility, and understanding realistic perspectives of disability.
PS23	(Berget et al., 2016)	Advances of visual content in text search, 21 participants with dyslexia and 21	Presenting icons and words in a list structure will benefit both groups in terms of search performance.

		controls	
PS26	(Sayago & Blat, 2010)	E-mailing (ethnographical study), 388 older people	Barriers, such as cognitive load, difficulties using input devices, and perception of visual information are recognized. Cognitive difficulties are much more relevant than difficulties in reading from the screen.
PS29	(Pérez-Espinosa et al., 2017)	Speech-based systems, 62 participants (31 elderly and 31 younger)	A method of recognizing paralinguistic phenomena in a speech, such as shouting, or hesitation could be used to estimate the quality of an interaction.
* PS36	(Shpigelman et al., 2009)	E-mentoring, 13 pupils with physical, emotional, behavioral, or intellectual impairment	E-mentoring with peers can improve personal development and empowerment.
PS46	(Alghabban et al., 2017)	Multimodal interface for learning	The use of multimodalities (images, audio, and text) for content supports learning.
PS72	(Kennedy et al., 2011)	Best practices for building websites for people with intellectual disabilities, 31 web designers and developers with 29 people with intellectual disabilities	Images to communicate core content; simple navigation; simple text; short sentences; voicing to narrate pages; and incorporate video, animation, and sound; the attitudes of decision-makers; engagement with stakeholders.
ICF Domain Code: Activities and participation (d) **ICF Sub-Domain Code:** Mobility (d4)			
PS2	(Liang et al., 2017)	243 participants with physical disabilities (difficulties walking, climbing stairs, lifting heavy groceries, or getting in and out of bed)	"Physical disability weakens the effect of information quality on perceived risk, strengthens the effect of system quality on perceived risk, and strengthens the effect of perceived benefits on information use."
PS4	(Seaborn et al., 2016)	Mixed-reality gaming for powered chair users, 13 adult participants who use a powered wheelchair	Mixed-reality game design should consider device and UI accessibility; inclusion of player skills allowing them to improve these; socialization with others; and game challenge.
* PS13	(Gerling et al., 2016)	Multiple foci. See previous description.	
PS28	(Barbosa et al., 2018)	Context-aware systems to assists wheelchair users, 10 wheelchair users	The use of ubiquitous technologies to support accessibility for wheelchair users are useful and acceptable.
* PS62	(Jaeger, 2006)	Multiple foci. See previous description.	
Accessibility itself (not in ICF)			
PS1	(Newman et al., 2017)	18 young people (10-18) with a physical disability (CP) acquired brain injury, 17 parents	Intensive, personalized and long-term support from within and beyond (peers and tutors) the family to get online is required. Parents' limited IT confidence, IT knowledge and access to appropriate AT influences the amount of support required.
PS14	(Mäkelä & Vellonen, 2018)	Education tools for special education, 57 participants special education teachers and school assistants	Do-it-yourself tools can give special educators a more active and creative role in technology adoption and benefit special education by increasing accessibility, motivation, and interaction possibilities.
PS21	(Cairns et al., 2019)	Accessibility in games, Persons with disabilities	Accessibility in games should not only consider whether people can operate the games but also their perceived experience.
PS22	(Raisamo et al., 2019)	Human augmentation, Persons with different disabilities (conceptual)	Integrated and intelligent wearable systems are the next progression in augmenting human abilities, but they have also potential ethnical and societal issues.
PS25	(Little et al., 2005)	Public space systems privacy and accessibility design, 60 participants	Screen sizes in public space systems, such as ATMs, affect users' perception of privacy.
PS27	(Dyson & Haselgrove, 2001)	Reading speed and line length, 36 participants	"A medium line length (55 characters per line) appears to support effective reading at normal and fast speeds."
PS32	(Santana & Baranauska	A remote evaluation tool for usage patterns,	By considering data of real usage patterns, potential usability and accessibility problems can be identified.

	s, 2015)	180 participants	
PS34	(Brajnik et al., 2011)	The effect of expertise on web accessibility evaluation, 19 expert and 57 non-expert judges	Expertise matters in the quality of accessibility evaluation, especially in validity and reliability.
PS35	(Vollenwyder et al., 2019)	Web practitioners' intention to consider web accessibility, 342 practitioners, Web questionnaire	Web practitioners' intention to consider accessibility is influenced by users' promotion of their needs, the role of professionalism, and desire for a high-quality product.
* PS36	(Shpigelman et al., 2009)	Multiple foci. See previous description.	
* PS37	(Santarosa et al., 2014)	Multiple foci. See previous description.	
PS38	(Ruiz et al., 2011)	Design for all, persons with hearing impairment	Multimodality in input and output modalities can be used to design inclusive technologies.
PS39	(Martins et al., 2017)	Accessibility evaluation procedure, Conceptual	Automatic web accessibility evaluation, manual web accessibility evaluation, and web usability heuristics evaluation should be conducted to identify accessibility and usability issues.
PS40	(Link et al., 2006)	Accessibility and acceptance of virtual human technology, 50 telephone interviewees	Responsive virtual human technologies with improved speech recognition have a potential for training and educational purpose.
PS41	(S.-H. Li et al., 2012)	WCAG study, Conceptual	Transforming WCAG-compliant webpages to correspond with updated versions does not require a full revision of the webpages.
PS42	(Lazar et al., 2004)	Web practitioners' intention to consider web accessibility, 175 webmasters, A survey	Societal foundations, stakeholders' perception, and web development influence web accessibility.
PS45	(Alkhattabi et al., 2011)	Information quality, 27 students	Availability, relevancy, accessibility, and response time indicate accessibility quality factors.
PS48	(Owei & Maumbe, 2006)	E-services in developing country, Conceptual	Strategies for e-service modeling, design, development, implementation, marketing, and access are needed for integration.
PS49	(Iivari et al., 2020)	Accessibility as a criteria of reusability in design science research, Conceptual	Design principles for IT artifacts should be accessible to be reusable.
PS52	(Matthews et al., 2020)	Pupillary response during interaction, 40 participants	Pupillary response indicating arousal (as frustration) during interaction is a potential setting in usability and accessibility lab testing.
PS53	(Sharp et al., 2020)	Sociocultural factors and capacity building in interaction design, 10 participants	Synergy between local design practices and interaction design practices is recommended.
PS54	(Kuzma, 2010)	UK governmental websites, 130 websites evaluated	Sites are not meeting legal mandates and industry accessibility guidelines. Tools should encourage web designers to comply with requirements when creating new sites.
PS55	(Lazar et al., 2013)	Governmental websites, 25 websites inspected by a total of 150 human inspections	Website development and redesign should apply fully accessible templates.
PS56	(N. E. Youngblood, 2014)	Assessment of the development of accessibility in governmental websites, 60 websites tested	Accessibility compliance has not improved substantially in 10 years.
PS57	(King & Youngblood, 2016)	U.S. governmental websites, analysis of 34 websites for voting	Governmental e-voting has accessibility issues. Development should use guidelines and usability heuristics.
PS58	(Yu & Parmanto, 2011)	U.S. governmental websites, 50 websites evaluated	U.S. state government websites perform better in terms of accessibility compared to the federal government and commercial websites
PS59	(Wentz et al., 2014)	Sign-up system to receive governmental emergency-related	Sign-up system is not accessible even when messages are. Government procurement processes

		messages, 26 counties evaluated	need to be used more effectively to enforce accessibility.
PS60	(Olalere & Lazar, 2011)	U.S. governmental websites, 100 federal websites evaluated	90% of the web pages had accessibility violations. Web pages should apply Section 508.
PS 61	(Shi, 2007)	Chinese governmental websites, 399 websites evaluated with evaluation tools	Web pages had WCAG problems. Specific group managed by government should ensure the law is followed.
PS63	(Fagan & Fagan, 2004)	U.S. governmental webpages, automatic evaluation for 50 websites	Users with AT, US states websites are not accessible. Adoption of guidelines is crucial.
PS64	(Henninger, 2017)	U.S. governmental information in websites, Case study concerns 500 undergraduate students	Accessibility of information is far more multidimensional and multiperspective than simple discoverability and usability.
PS65	(Lazar et al., 2010)	Accessibility policy	The implementation of regulations lags. Education about legal requirements and regulations as well as appropriate and effective ways to interact with persons with disabilities.
PS66	(Yi, 2015)	Web accessibility compliance with Section 508 and public libraries' IT budgets, 20 public library systems evaluated	There is no significant association between the public library websites' accessibility and their IT budgets, which suggests that awareness of web accessibility is the major challenge.
PS67	(S. A. Youngblood & Youngblood, 2018)	Accessibility evaluation of Local Emergency Management Agencies' website, 42 websites evaluated	The most compelling example of failure is the use of appropriate alternative text attributes.
PS68	(Navarro-Galera et al., 2016)	Online dissemination of information in 17 Spanish regional governments	Developers and managers must study how to respond to the unmet needs of users.
PS69	(Y. Li & Shang, 2020)	E-government service quality dimensions: accessibility, Survey with 1650 respondents	Technical features, such as system quality, accessibility, and reliability, only have weak effects on citizens' perceived service value.
PS70	(Kanayama, 2003)	Accessibility policy making	Regulations only encourage businesses to consider accessibility issues for people with disabilities. Policy should enforce the promotion of accessibility.
PS71	(Stienstra et al., 2007)	Collaboration between governments, industry, and disability advocacy organizations	Differences in motivating forces between disability advocacy organizations and the IT industry should be considered.
PS73	(Neufeldt et al., 2007)	Difference of promoting accessibility in public and business	Research and business interests, goals, differences in funding require communication and trust between research and the private sector.
PS75	(Kamoun & Basel Almourad, 2014)	Dubai governmental webpages evaluation, 21 websites evaluated	Accessibility should be given a higher priority in general evaluation.
PS76	(E. Loiacono & McCoy, 2004)	The Americans with Disability Act (ADA), Companies' website accessibility evaluation, 45 websites evaluated	Only 9% of the websites included in the study have accessible home pages. Companies need to act proactively in creating accessible websites.
PS77	(Nicholas C. Romano Jr, 2002)	Fortune 250 Companies' website accessibility evaluation, 248 websites evaluated	75% of websites have accessibility errors. Solutions: use of guidelines; automatic and human reviews; text-only versions; alternative methods for obtaining information (phone number, e-mail, or postal).
PS78	(Hackett & Parmanto, 2009)	Accessibility evaluation of a website, 50 websites evaluated	Evaluating only the homepage is not sufficient to determine the accessibility. First-level pages should be included for more accurate results.
PS79	(Hackett & Parmanto, 2005)	Higher education websites, 45 education websites evaluated	Forgetting to supplement alternative text for images is an issue that causes accessibility barriers for persons with disabilities.
PS80	(Parmanto & Zeng,	Web accessibility evaluation, 1518 websites evaluated	Metric for quantitatively measuring the content accessibility (based on WCAG) is proposed.

	2005)		
PS81	(Splendiani & Ribera, 2016)	Accessibility of visual content in academic articles, 30 articles in PDF format evaluated	The information presented in figures, graphs, and other image-related texts should be designed to ensure that people with visual disabilities can receive the same information. This can be done with text alternatives, the use of captions, mentions, text labels, and metadata.
PS82	(Lorca et al., 2012)	The effect of firm size and national culture/legislation on level of web accessibility	Both size and culture have a significant effect on web accessibility.
Note: *Indicates studies with multiple foci.			

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Designing Heuristics for Accessible Online Text Production

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Abstract. Governments and public organisations provide digital services and share information on websites, so web content needs to be accessible to all citizens. Text remains the main form of providing information, and reading is the primary way to interact with digital services. However, existing guidelines are not adequate for content creators in public organisations. The wide scope and technicality of these guidelines make them confusing, difficult to understand and challenging to implement. To respond to this emerging need, in this paper, we contribute improvements to the guidance of accessible text production by proposing heuristics with a design science approach. Specifically, we (1) review accessibility guidelines and determine improvement factors related to text accessibility, (2) establish a design and evaluation workshop with 38 students, and (3) verify the feasibility of the proposal with content creators. Our evidence shows that the proposed accessibility heuristics are clear and easy to understand, and they are useful for content creators.

Key words: accessibility heuristics, text accessibility, web accessibility, design science.

1 Introduction

The number of users of digital public services is constantly increasing, as more and more services are becoming available only through websites or mobile applications (European Commission, 2015). For example, in Finland, where the use of digital public services is highest in EU countries (year 2019) (European Commission, 2015), the digitalisation

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of public services has been one of the government's flagship projects since 2015 (Ministry of Finance [Finland], n.d.). The provision of digital services is enshrined in law; in Europe, an EU directive (Directive (EU) 2016/2102) on the accessibility of public sector bodies' websites and mobile applications requires these public entities to develop their online services (Directive 2016/2102 (2016) of the European Parliament and of the Council of 26 October 2016, 2016; European Telecommunications Standards Institute, 2015).

Because of the heterogeneous user communities of digital services, websites, mobile applications, and their content need to be accessible and understandable. In digital services, texts and linguistic elements convey meaning (Isohella & Nuopponen, 2016). Despite the increasing amount of audiovisual content, a significant proportion of online content remains in textual form (Kalender et al., 2018), so reading is one of the primary ways to interact with digital services (Rello et al., 2016). In this regard, knowledge of the factors serving as barriers to screen reading is urgently needed (Dyson & Haselgrove, 2001)there is an urgent need to increase our knowledge of factors influencing reading from screen. We investigate the effects of two reading speeds (normal and fast. However, studies that develop guidelines for accessible texts often focus on certain groups, such as people with dyslexia (Li et al., 2019; Miniukovich et al., 2017; Rello et al., 2012), thus excluding individuals with other needs.

Although accessibility guidelines, such as the Web Content Accessibility Guidelines (WCAG), offer great help for web practitioners, webmasters and web developers, websites often remain inaccessible (Lazar et al., 2004; Vollenwyder et al., 2019). One reason for this is confusing guidelines (Lazar et al., 2004; Minin et al., 2015; Vollenwyder et al., 2019). The majority of web practitioners who have technical expertise have at least a basic awareness of web accessibility that individuals in non-technical roles do not necessarily possess (Vollenwyder et al., 2019). Content creators are one of the groups of practitioners who are struggling with the question of how to create accessible content for websites. A content creator is a practitioner often without web technological expertise. Their responsibility is to create and update the content of an organisation's website. This content may consist of any digital media format, such as images, videos or audio, but it is mostly text. Even though some content creators may have an understanding of web technologies, existing guidelines are relatively technical, as they consist of techniques to improve the programming of a website (Leuthold et al., 2008; Martins et al., 2017). The scope of existing accessibility guidelines is too wide and technically specified for the use of content creators in public services. There is a need for clear guidance on how accessible text can be produced for websites.

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Our research question is as follows:

What design heuristics can support content creators in producing accessible online texts?

To answer this research question, using the design science approach, we first investigated available accessibility guidelines and identified practices related to producing accessible text. Second, from these findings, we provided a list of heuristics that were evaluated and improved in a workshop. Third, the heuristics were revised again. Finally, the practical feasibility of the revised version was discussed in interviews with online content creators from sampled organisations.

In this paper, we contribute improvements to the guidance of accessible text production. Our goal is to design a proposal for accessibility heuristics (i.e., general principles that are easy to use and understand for content creators in public services for creating accessible textual web content). This paper makes the following contributions. First, the factors that improve text accessibility are categorised and summarised in a literature synthesis. Second, the proposed heuristics for online text production for content creators in the public sector are presented. These heuristics are the outcomes of the literature review, two design and evaluation iterations (i.e., a workshop with students [N = 38]) and interviews with three content creators.

The rest of the paper is organised as follows. The next chapter presents the background. Chapter 3 describes the design science methodology. Chapter 4 presents the results of design and development, including the literature review, the results of the design iterations and the proposed heuristics. Chapter 5 presents the discussion and concluding remarks.

2 Background

Accessibility requirements for web and mobile services in the EU directive are based on the European Standard "Accessibility requirements suitable for public procurement of ICT products and services in Europe" (EN 301 549 V1.1.2 2015-04). The foundation of accessibility requirements is the WCAG, developed by the Web Accessibility Initiative of the World Wide Web Consortium (W3C). WCAG are structured into three levels of compliance: A (lowest), AA and AAA (highest) levels. In legislation, the EU directive recommends following the middle-level AA. Guidelines are organised into four principles: perceivable, operable, understandable and robust (W3C, 2018). Legal requirements consist of all documents and software that are embedded, rendered or

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intended to be rendered with web pages (Directive 2016/2102 (2016) of the European Parliament and of the Council of 26 October 2016, 2016; European Telecommunications Standards institute, 2015).

In this paper, accessibility is defined as "appropriate measures to ensure to persons with disabilities access, on an equal basis with others, to the physical environment, to transportation, to information and communications, including information and communications technologies and systems, and to other facilities and services open or provided to the public, both in urban and in rural areas" (United Nations, 2006). This definition is from the United Nations Convention on the Rights of Person with Disabilities, and it also emphasises that state parties should promote the design, development, production and implementation of information accessibility at the early stage of information and communication technology processes. According to Petrie et al. (2015), accessible websites need to be designed and developed to support usability. One of the most cited theories of usability describes it based on five attributes that emphasise usefulness: (1) easy to learn, (2) efficient to use, (3) easy to remember, (4) contains few errors and (5) subjectively pleasing (Nielsen, 1993).

Previous studies contributing design guidelines to improve web page readability often have a certain focus group. For example, Miniukovich et al. (2017) provided design guidelines to improve web readability. They reviewed existing readability guidelines and obtained a set of 61 readability guidelines. However, as they addressed the issue of having existing guidelines that are too many, too generic and poorly worded or that lack cognitive grounding, they conducted a series of workshops with design and dyslexia experts and a user study with dyslexic and average users to compile a set of 12 core guidelines (Miniukovich et al., 2017). Rello et al. (2012) offered a set of dyslexic-friendly guidelines with the following parameters for the layout of web text to improve accessibility for people with dyslexia: grey scale in the font (10%), grey scale in the background (90%), colour pairs (creme/black), font size (26), character spacing (+7%), line spacing (1.4), paragraph spacing (2) and column width (77 characters/line). Despite the focus group, the authors argued that the use of web accessibility practices for dyslexic users is beneficial for all (Rello et al., 2012). These parameters are similar to web browser settings, such as Mozilla Firefox's *Reader View* for modifying the web page layout. Li et al. (2019) investigated the impact of web browser reader views on reading speed and user experience. The authors conducted an online study with 391 participants, of which 42 were self-diagnosed with dyslexia. They found that the reader view increases the reading speed of readers by 5%, on average, and there is a similar rate for readers self-diagnosed with dyslexia (Li et al., 2019). Moreover, the average

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perceived readability and perceived classical aesthetic (e.g., clean, pleasant) increased significantly within both groups.

According to studies by Li et al. (2019), Miniukovich et al. (2017) and Rello et al. (2012), web text design practices for dyslexic users are beneficial for all.

However, a number of issues that require further examination can be highlighted to generalise existing guidelines:

- Existing text accessibility principles often provide guidelines on how to formalise text for faster reading speed or better readability. They ignore guidance for text content formalisation in order to have easier-to-understand text or guidance for content structure organisation in order to have easier-to-perceive text.

- Existing formulations of text accessibility guidelines do not provide explanations for achieving this aim, which may affect an individual's motivation to follow them.

- Existing guidelines are designed to cover instance problems with instance solutions for specified users (e.g., dyslexic). Little attention is given to the person implementing the design principles. This person can be, for example, a content creator who uses design principles in practice or a theoriser who uses them to capture knowledge (Gregor et al., 2020).

Next, we describe our method.

3 Method

Our research aims to deliver solutions to text accessibility for the use of practitioners. We adopted the design science research methodology process model by Peffers et al. (2007) presents, demonstrates in use, and evaluates a methodology for conducting design science (DS to achieve our research aims. We conducted our study in three conceptual phases: problem identification and objective definition (phase 1), artefact design (phase 2) and artefact demonstration and evaluation (phase 3).

In the first phase, we performed a literature review and content analysis of our selected primary studies (PSs) to identify the inadequacy of existing guidelines, and we made additions from other literature. In the second phase, we formulated the heuristics in the design cycle. In the third phase, we conducted two design iterations. In the first one, we established a design and evaluation workshop. In the second design iteration,

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we conducted interviews. By design iteration, we mean the process of applying extracted data.

During our research process, we formulated three versions of the heuristics. The first version (VER1.) is based on the results of the first phase, the second version (VER2.) is based on the results of the first design iteration (workshop) in the third phase and the proposed heuristics (final version) are based on the results of the second design iteration in the third phase (see Figure 1). The evaluation of the heuristics was conducted during the workshop and interviews. Next, we describe the literature review, design iterations and evaluation in detail.

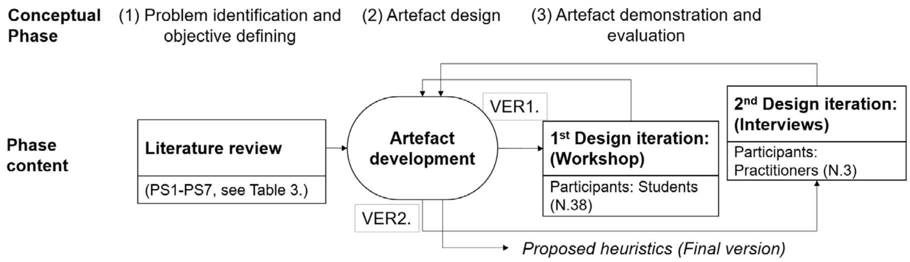

Figure 1. Research process overview (adopted and modified from Peffers et al. 2007)

3.1 Literature review

To collect prior knowledge on our research topic, we conducted a literature review. We aimed to summarise findings to identify any gaps (Gregor & Hevner, 2013; Okoli, 2015) in current guidance and obtain reusable items (Peffers et al., 2007)presents, demonstrates in use, and evaluates a methodology for conducting design science (DS for developing the first version of the accessibility heuristics scoped to online text. We focused on heuristics that provide guidance on how to formalise and produce text, considering linguistic elements to conform to accessibility.

This review process involved two steps. First, we developed a review plan for searching the literature. We formulated the search term 'accessibility heuristics' and the search string 'text' AND 'accessibility heuristics'. We performed the search on Google Scholar with a date range of 2000-2019. The first search term returned 387 papers, and the search string returned 189 papers. We then included only journals and conference papers with a search term/string stated in the title, abstract or keyword list. After the exclusion of papers with these criteria, 34 papers remained. Next, we analysed the content of the papers based on the full article and included only those studies that provided heuristics or guidance relating to text accessibility. At this point, we manually added

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the WCAG and ICT for Information Accessibility in Learning (ICT4IAL) guidelines to our set. WCAG are amongst the major guidelines concerning web accessibility. ICT4IAL guidelines are a result of the Accessible Information Provision for Lifelong Learning project, co-funded by the European Commission's Lifelong Learning Transversal Programme (European Agency for Special Needs and Inclusive Education 2015). We chose the ICT4IAL guidelines because they are directed to non-expert actors for the creation of achievable knowledge in their work environment (European Agency for Special Need and Inclusive Education, 2015). Thus, they fit well for our purpose—the heuristics we create are meant to serve a wide range of users, especially non-experts. Finally, we included seven papers or guidelines for further analysis. The results of the literature review are presented later in Section 4.

3.2 Artefact development and design iterations

The key step in design science research is artefact design and development (Brown et al., 2011). The heuristics were built based on two design iterations: a workshop and interviews. We analysed the data obtained from the design iterations and formulated the heuristics in the artefact development phase. In the following, we describe the design iteration procedure.

First design iteration (workshop)

In the first design iteration, we demonstrated our first version of the heuristics as a candidate solution for accessible text production (Mettler et al., 2014) in a workshop to evaluate and enhance the heuristics. The workshop focused on contributing improvements to three areas: 1) the content and formulation of the heuristics, 2) their usability and 3) their utility.

The workshop was held with 31 university master's-level students, of which 22/31 (71%) were females and 9/31 (29%) were males. Their average age was 29 years, and their age range was 21-51 years. The majority of the students 23/31 (74%) were from the technical communication programme. They had some experience in website design and content creation, and almost everyone had work experience in companies or public sector organisations. Therefore, the students were regarded as intermediate content creators (on user types, see, e.g., Cooper et al. 2007). The workshop was held in February 2020 as part of a 5 ECTS web content accessibility course. The prerequisite for the course was an introductory course in human-computer interaction. The students participated voluntarily. They were asked for permission to use their work in this research, and the decision not to participate had no impact on the students' grades.

The workshop lasted for 90 minutes. As the course was organised in a flexible way, allowing the students to participate synchronously on-site (N = 16) or via a Zoom video conference (N = 15), the workshop was organised in a similar way. To simulate real work conditions, we had the students participate in on-site work in pairs and via Zoom individually. They were already familiar with the heuristics, as we had presented these two days earlier in a lecture titled "Strategies for producing textual online content". The students were given the role of content creators in public organisations. They were asked to choose the website of a Finnish public organisation from a list given by their instructors. They first evaluated the web content heuristic by heuristic and took notes. They then summarised their findings in a questionnaire, were asked to look at the heuristics row by row and then commented on each of the heuristics in terms of understandability, clarity of content, flawlessness and anything that comes to mind that they consider important regarding content. At this point in the study, we concentrated on the content and not the layout of the heuristics, as organisations may want to use their own templates. This questionnaire was also used in the evaluation. Thematic content analysis (Zhang & Wildemuth, 2017) was used to examine the qualitative data (i.e., responses to the open-ended questions of the questionnaire regarding the content of the heuristics).

Second design iteration (interviews)

After revising the heuristics based on the results of the first iteration, we conducted the second design iteration with three content creators (P1-P3). The participants were invited to an interview to evaluate the feasibility of the heuristics and to contribute improvements to them. We sent invitations directly to individuals involved in content creation. They were invited purposively from different public organisations under the same accessibility legislation: a university, a government agency and an association dealing with special groups. Participation was voluntary.

The participants had different years of work experience in content creation—P1: 8 years, P2: 4 years and P3: 15 years. We sent the proposed heuristics to the participants a week before the interview so that they could familiarise themselves with the heuristics beforehand. To simulate real-life conditions, we did not give any instructions on how to use the heuristics when we sent these to them. Two face-to-face interviews were conducted in June 2020 in the participants' workplaces, and one was conducted in August 2020 on the phone. The data were gathered through semi-structured theme interviews

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(Wengraf, 2001), which each lasted about two hours. The themes for the interviews were 1) the current situation regarding accessibility in the relevant organisation, 2) the content of the proposed heuristics and 3) the feasibility of the heuristics. The improvements suggested by the interviewees for the content are discussed in Chapter 4.

3.3 Evaluation

As evaluation is one of the key activities in design science (Venable et al., 2016), we developed an evaluation strategy for assessing the proposed heuristics. In the conceptual phase—artefact demonstration and evaluation—we performed the evaluation, first, during the workshop as an ex ante evaluation (Sonnenberg & vom Brocke, 2012; Venable et al., 2016) to confirm proof of concept (Gregor & Hevner, 2013). This evaluation included the following evaluation criteria: learnability, utility, memorability, flawlessness and consistency. Second, we conducted the evaluation during the interviews as an ex post evaluation (Sonnenberg & vom Brocke, 2012; Venable et al., 2016) to verify the expected value (Gregor & Hevner, 2013) for content creators, i.e., assessing with real users (Gregor & Hevner, 2013; Venable et al., 2016). This evaluation included criteria such as importance, feasibility and utility to practice (Sonnenberg & vom Brocke, 2012). The evaluation strategy involved a framework proposed by Venable et al. (2016) with the following components: why, when, how and what to evaluate (see Table 1). We conducted the assessment concerning the *validity*, *utility quality*, and *ef-*

Why evaluate? (Verification of…)	*When to evaluate? (Phase of the research)*	*How to evaluate? (Method)*	*What to evaluate? (Target)*
Validity	During the workshop, during the interview and after the workshop	Open-ended questions, interviews and reflection paper	Importance and feasibility
Utility	During the workshop and during the interview	Open-ended questions and interviews	Utility
Quality	During the workshop	Open-ended questions	Flawlessness and consistency
Efficacy	During the workshop and after the workshop	Open-ended questions and reflection paper	Learnability and memorability

Table 1. Evaluation framework adopted from Venable et al. (2016)

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ficacy (Gregor & Hevner, 2013) of the heuristics as follows. To verify their *validity*, we evaluated *importance* and *feasibility* during the first iteration in the workshop. We used open-ended questions in a questionnaire filled out by the students during and after the, as well as during the second iteration in the interview. After the workshop, the students were given an individual assignment to complete outside the class. They were asked to create textual content for an organisation's website using heuristics and then to write a reflection paper on it. Specifically, they were advised to evaluate usability-related issues, such as learnability and memorability, but especially utility, as well as the validity of the workshop outcomes. By having the students work with heuristics, we prepared them to evaluate the validity, utility, quality and efficacy of the heuristics. The data consisted of 31 reflection papers ranging from one A4 to two sheets in length.

The evaluation of *utility* was conducted with open-ended questions in the questionnaire completed by the students during the workshop and the interviews. The *quality* of the heuristics was evaluated during the workshop with open-ended questions in the questionnaire related to the flawlessness and consistency of the heuristics. *Efficacy* was evaluated during the workshop with open-ended questions in the questionnaire related to the learnability and memorability of the heuristics and after the workshop in an assignment followed by a reflection paper.

4 Results

In this chapter, we report the results of the literature review and design iterations, including the evaluations, and present our proposal for the heuristics. In order to construct the heuristics, we extracted those factors improving text accessibility from the PSs as reusable items (Peffers et al., 2007) presents, demonstrates in use, and evaluates a methodology for conducting design science (DS to formalise our first version of the heuristics, which we supplemented with other literature. We then revised the heuristics based on the workshop findings in the first design iteration. Then, in the second design iteration with the revised version, we interviewed content creators from three different organisations and included the results in the final version. In the following sub-chapters, we describe the results of these steps.

4.1 Results of the literature review

We included seven papers or guidelines as PSs for further analysis (see Table 2).

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ID	*Title*	*Name of the Heuristics/Guidelines*	*Author(s)*	*Year*
PS1	Applying heuristics to accessibility inspections	IBM web accessibility heuristics: WCAG1.0, Nielsen Accessibility Guidelines (2001), IBM Web Accessibility Checklist 3.01, Guidelines for UK Government Web Sites (2004), Section 508 Web Standards (2004)	Paddison, Claire and Paul Englefield	2004
PS2	A study of web accessibility barriers for older adults, and heuristics evaluation of email websites based on web accessibility heuristics for older adults by AARP	WAI AGE guidelines (Web Accessibility Guidelines for older adults by W3C) and heuristics evaluation based on AARP heuristics	Ilyas, Mahanum	2012
PS3	Designing location-based learning experiences for people with intellectual disabilities and additional sensory impairments	Heuristics for good design (Accessibility part)	Brown, David J., David McHugh, Penny Standen, Lindsay Evett, Nick Shopland and Steven Battersby	2011
PS4	Toward accessible mobile application design: developing mobile application accessibility guidelines for people with visual impairment	Mobile Application Accessibility Heuristics for people with visual impairment	Park, Kyudong, Goh Taedong and So Hyo-Jeong	2015
PS5	Evaluation of the effectiveness of a tool to support novice auditors	Accessibility Evaluation Assistant (AEA) heuristics checks	Bailey, Christopher and Elaine Pearson	2012
PS6	Web Content Accessibility Guidelines (WCAG) 2.1	Web Content Accessibility Guidelines (WCAG) 2.1	World Wide Web Consortium (W3C) Web Accessibility Initiative (WAI)	2018
PS7	Guidelines for Accessible Information	Guidelines for Accessible Information. ICT for Information Accessibility in Learning (ICT4IAL) (Section 1: Making your text accessible)	The European Agency for Special Needs and Inclusive Education	2015

Table 2. List of primary studies

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Next, we analysed the content of the PSs to categorise the guiding factors. We found that every recommendation on text accessibility was related to text format, structure or content (see Table 3).

Factors that Improve Text Accessibility	*Category*	*Instances (ID)*
Colours and the use of bold and italics are not the only methods for conveying meaning.	Formatting	PS1, PS5, PS6, PS7
The text size in documents is a minimum of 12 pt; the user interface should allow text resizing.	Formatting	PS1, PS2, PS5, PS7
Sans serif fonts, such as Arial, Verdana, Helvetica, Tahoma and Trebuchet MS, are used.	Formatting	PS7
Bullets are used.	Formatting	PS7
Text spacing (line spacing: 1.5 times the font size, paragraphs: two times the font size, letter spacing: 0.12 times the font size, word spacing: 0.16 times the font size)	Formatting	PS6
Left alignment is used.	Formatting	PS7
Alt text for non-text elements is used.	Structure	PS1, PS3, PS4, PS5, PS6, PS7
Consistent navigation and headings with a logical order	Structure	PS1, PS4, PS5, PS6, PS7
Links are highlighted differently from the text with an action word in the label.	Structure	PS2, PS4, PS5, PS6, PS7
Simple language is used.	Content	PS3, PS6, PS7
The full meanings of abbreviations and acronyms are provided the first time they are used.	Content	PS6, PS7
Important information is provided first.	Content	PS4
Short summaries of content are provided.	Content	PS7
Appropriate language for the audience is used.	Content	PS6

Table 3. Identified factors that improve text accessibility based on the PSs

In the following sub-chapters, we describe the findings on these categories in detail.

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Text formatting

The guidelines in the PSs provided a relatively large number of precise instructions for text formatting. Text formatting refers to text style definitions, such as font, font size, bold and italics, and line spacing, to name a few. The use of formatting makes the text easier to perceive and interpret. ICT4IAL recommends using fonts such as Arial, Helvetica or Verdana, as well as Tahoma or Trebuchet MS, which are designed for reading on the screen (PS7). ICT4IAL recommends a font size of at least 12 pt (font size of Cascading Style Sheets, CSS) to be used in documents ignoring text size recommendations in titles or on a website (PS7). The website design should provide configuration for resizing text (PS1, PS2, PS5, PS6) and changing colours (PS6) by users. In addition, the WCAG instruct that the text size should be scalable without assistive technology (up to 200%) and without losing any information (PS6).

Both the WCAG and ICT4IAL consider line spacing, text spacing and letter and word spacing to be more important than font selection. The WCAG recommend the line spacing to be at least 1.5 times the font size, the text paragraph spacing at least two times the line spacing, the letter spacing at least 0.12 times the font size and the word spacing at least 0.16 times the font spacing (PS6). Such precise formatting definitions can rarely be made with a content management system's text editor tool, requiring either CSS-style definitions or other parts of the management system.

According to the PSs, colours, bolding or italics should not be used for conveying meaning (PS1, PS5, PS6, PS7). ICT4IAL states that text should be left aligned, in which case alignment on both edges should be avoided (PS7). Text should be written horizontally, and text written vertically should be avoided (PS7). The guidelines recommend using bullets for a list (PS7).

Text structure

The accessibility guidelines almost invariably recommend alternative text, the so-called alt text, to elements that are not text (PS1, PS3, PS4, PS5, PS6, PS7). The WCAG provide guidance on this matter even at the lowest A level. Alt text should be given, for example, to an image that represents information. This way, people who cannot perceive an image visually get the same information with a screen reader. However, the instructions do not specify in detail how to write, for example, the content of a verbose and informative image. The guidelines also emphasise that text should not be presented in image format.

The second extensive guidance refers to issues related to operability and navigability. Of these selected guidelines, the most common instruction refers to considering the

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contribution of the logical use of a heading structure to support navigation (PS1, PS4, PS5, PS6, PS7).

Links in the text should be named in such a way that the user understands the purpose of the link and where it leads (PS5, PS6, PS7). Links should be highlighted differently from other texts to draw attention (PS4) and should be named with an action word (PS2). In addition, ICT4IAL recommends that the URL of the link must be presented in its entirety, for example, in a separate list, so that the same information is retained when printing.

Text content

The third principle of WCAG 2.1 is understandability. One A-level criterion, one AA-level criterion and three AAA-level criteria are given to achieve this. The A and AA level (legal requirements) guidance provides only some technical solutions. For example, the A-level criterion is the language of the page (i.e., the default natural language of each web page can be determined programmatically), and the AA-level criterion instructs specifying words or phrases with language tags if they are in a different language from that of the body text. In practice, this is done by marking the HTML language with a so-called lang-attribute or language tags, which tell search engines or user agents in which language the web page or particular word/phrase is.

However, the PSs provided some textual guidelines related to (1) language, 'Use the simplest possible language appropriate to your document' (PS3, PS6, PS7); (2) abbreviations and acronyms, 'When using abbreviations or acronyms, mention the full names when the abbreviations or acronyms are used for the first time' (PS6, PS7); (3) summaries, 'Add short summaries of the content or paragraph, where possible' (PS7); and (4) order, 'Provide important information first' (PS4). The PSs contained only a few general remarks related to text and linguistic elements.

As there were only a few recommendations concerning text production and linguistic elements in the PSs, we expanded our search and made supplements to strengthen the guidance that we will include in the first proposal of the heuristics. From the results of the literature review, we identified the lack of a detailed explanation for why proposed suggestions are necessary to implement. Therefore, we applied manual precision searching for text size, font type and simple language to have more detailed instructions.

In addition to the PSs, we found that Rello et al. (2016) recommended using a text size of at least 18 pt. up to 26 pt. to improve readability and comprehension when reading on the screen. The use of sans serif font types, such as Arial and Verdana, has a significant impact on readability, especially for people with dyslexia, whereas itali-

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cisation of text, or the use of italics, has been found to slow down and make reading difficult regardless of the font used (Rello & Baeza-Yates, 2013). As the development of plain language has a long tradition (Mazur, 2000) in pursuing an understanding of the text (Redish et al., 2010), we extracted two of the most critical plain language guides to expand our first proposal of the heuristics: (1) write short sentences and (2) address readers directly with *you* or the imperative *do* (Redish et al., 2010).

Finally, we formulated the first version of the heuristics based on the factors presented in Table 2 and the supplements. The heuristics were presented in the form of an instruction. For example, the factor 'bullets are used' is expressed as 'use bullets'.

4.2 Findings from the first iteration (workshop)

The aim of the workshop was to evaluate the heuristics in terms of their content, usability and utility. As the crucial point in the first design iteration was to refine the content of the heuristics, in this chapter, we focus on describing improvements that were made to have a refined version of the content of the heuristics. The findings on the assessment of the usability and utility of the heuristics are described in detail in sub-chapter 4.4.

Regarding understandability and clarity of the content of the heuristics, three themes emerged from the students' answers: (1) removal of irrelevant words and information, (2) insertion of clarifications and (3) removal of repetition. The evaluation done by the students showed that the heuristics included words or phrases that were unnecessary and that lengthened the documents. For example, the phrase 'Remember that' in the description of the first heuristic was regarded as irrelevant: 'Remember that the reader may only focus on your written text […]'. As a result, the description became shorter: 'The reader may only focus on your written text […]' (See the first heuristic, H1, in Table 4). Another example of an irrelevant phrase is in H6, 'Align the text to the left', which, in the evaluation version, was followed by another sentence: 'Don't squeeze too much text in a small space'. Students considered the sentence irrelevant, so it was removed.

Although the heuristics were regarded as clear and easy to follow (see sub-chapter 4.4), the students suggested some clarification for some heuristics, such as H3, 'Favour sans serif fonts, such as Verdana or Arial'. The heuristic had an explanation ('Verdana is one of the most popular and aesthetically pleasing fonts designed for on-screen viewing. Arial is slightly faster to read'), but a clarification of why sans serif fonts are preferred was required. Another clarifying sentence was therefore added: 'Sans serif fonts are simple, so they are clear and easy to read online'.

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The third theme in the students' responses dealt with repetition. For example, the explanation of H2, 'A larger font sizes improve online readability', contained information about font sizes in the evaluation version ('Larger font sizes, such as 18-26, [...]'. It was considered repetition, as the heuristic was already informing about font sizes: 'Use font sizes 18-26 for online content and 22-26 for headings, depending on the heading level'. Regarding flawlessness, the students did not report any writing or factual errors. As stated above, their findings and suggestions were related to word choice.

Except for H11, all the proposed heuristics had some suggestions for improvements. Using the findings from the first iteration, we revised and updated the heuristics and moved on to the second design iteration, as described in the following sub-chapter.

4.3 Findings from the second iteration (interviews)

The first impression of all the participants regarding the proposed heuristics was positive

> 'clear and nice structure; if I need help in content, I just refer to points 11-15 (P1)
>
> It looks good; it's nice that you have instructions first and then an explanation of why they should be done (P2).
>
> Clear and simple! But there are a few things I hope to have more information on (P3).

In the interviews, we discussed each heuristic one by one and asked for the interviewees' opinions on each of them. We asked whether they were easy to understand and easy to implement. The interviewees were also asked to provide suggestions for improvements. In the case of H10, P1 suggested providing more concrete instructions on how to formalise a link in the text. Based on experience, P1 suggested underlining the text and using the blue colour in the links. In addition to H10, P3 suggested naming the link that indicated the name of the website. Related to H1, P3 suggested additions to the description to avoid the use of bolding in titles, which is a common mistake. To respond to the suggested additions, we modified the explanation of H1 by adding 'Do not use bolding to indicate titles...' to the instruction, and for H10, we verified this suggestion by referring to the guideline for visualising links by Nielsen (2004); it states that underlines and the blue colour are the strongest perceived affordance of clickability. Responding to requirements to provide concrete instruction, we decided to define

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the heuristic more closely, adding 'with underlined blue colour' to the instruction and 'or the name of the website' to the explanation.

4.4 Results of the evaluations

We conducted the evaluation during the workshop, after it and during the interviews. The questionnaires in the workshop contained only open-ended questions because these were likely to elicit novel and unanticipated responses. In the evaluation after the workshop, we refer to the reflection papers written by the students after the workshop (see 3.3). In this chapter, we refer to them as post-workshop reflections.

In the following, we describe the evaluation in more detail. We present the results of the evaluation concerning the validity, utility, quality and efficacy of the heuristics. We illustrate the results by providing examples of the answers representing the majority of the responses.

Validity: In the questionnaire, we asked, 'How did it feel to use the list? Was it, for example, easy, nice, fun, difficult, complicated…? Justify your answer'. Thirty respondents (N = 31) felt positively about the heuristics. They described the list, for example, as easy and clear:

> The list was easy to use, and it controlled the viewing of the page well. It was clear, and the descriptions helped find concrete things in the text.

The respondents also described the list as nice and useful:

> [It's] nice, and the list makes the job easy. Definitely a good tool for those who do accessibility work. Without a list, the job can feel really big, and it can be hard to get a grip. [It's] a very useful list'.

One respondent reported that the list was difficult to use:

> The list was difficult to keep track of because of its layout; the use of colours could help structure different areas.

The third theme in the interviews with the three practitioners (P1-P3) considered the importance and feasibility of the heuristics. We asked, 'How would you rate the value of the guidelines? Would they be an added benefit to your work? The practitioners answered the following:

> The list is good; we have one infographic about accessibility in our organisation, but it's too plain. This list is good and gives instructions for a certain level of accessibility (P1).'

> Yes, sure, it's good… It helps a lot. All the things that it contains are important (P2).

> Good checklist! The web is full of instructions, longer and shorter. Are they reliable? They're good to place on the wall of the office and check if I have now taken them into account. I could think of keeping the instructions in my office room. The good thing is that there are instructions on what to do and then descriptions, especially for people who may not be familiar with accessibility issues (P3).

In the post-workshop reflections, the students (N = 31) commented on the feasibility of the heuristics. All respondents considered the heuristic list useful. In their responses, the list was characterised as a *guiding principle* or *aid*. According to these responses, the heuristics also worked well in creating textual web content and not just in evaluating it.

Utility: To the question 'How well did the heuristic list help you in making the assessment? Would you have passed the evaluation without the list?', all the respondents (N = 31) said that the heuristics helped them in conducting the accessibility assessment:

> Very much. Assessing accessibility would have been much more challenging without it. I would probably have first searched Google for some sort of list/piled up ripped data so that I'd come close to the same result. So, it greatly speeded up and facilitated the process.

Most of the respondents (61%) said that without the heuristics, they could not have made the assessment, or the results would not have been so accurate:

> I wouldn't have performed without the list. It was a lot of help in breaking down the evaluation into details.

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In the interviews, we also asked whether the practitioners would use the heuristics. As a sample, they answered the following:

> [When] in a hurry and when you have a lot to do, then such a guideline would be useful. Certain things go easily once you have done them before (e.g., font and line spacing). The instructions are specific enough that the user knows what to check (P1).

> It's good to have instructions in place, especially in organisations that produce a lot of content (P2).

> Yes, and I would share it with others (P3).

Quality: The assessment of quality (N = 30) of the heuristics was divided into flawlessness and consistency of the heuristics. As for flawlessness, we asked, 'Did you notice typos or factual errors in the text content? If so, what kinds?' Four respondents recommended different word choices for one heuristic, which was fixed.

As for consistency, we asked, 'When using the list, did you have to correct an assessment you had already made about the content of the website, for example, after noticing that an item you were evaluating only came up later in the list?' Sixteen respondents answered that they performed without any problems:

> There were no points in which I had to jump over them or go back.

Six respondents found contradictions in the guidance or heuristics that excluded others:

> Yes, heuristics 1 and 10 are a bit mutually exclusive if you think you'd like the listener to notice the links, as well. Heuristic 1 instructed avoiding all highlights, and heuristic 10 instructed taking advantage of them.

Therefore, we made additions to the description of H10 to provide more detailed information on how to highlight links. Four respondents commented on the order of the heuristics:

> I had to at one point; for example, when the font was being processed, I corrected an earlier point about highlights.

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However, these corrections were made to the revised version, and because of their clarity, further assessment was not needed.

Efficacy: The assessment of the efficacy of the heuristics was divided into learnability (N = 31) and memorability (N = 30).

As for learnability, we asked, 'How quickly were you able to leverage the heuristic list to assess the accessibility of textual web content? For example, did you initially have to spend time perceiving and understanding the heuristic list, or did you use it to start the evaluation quickly?' Twenty-five respondents said that the heuristics were fast to use and easy to understand:

> I was able to start the evaluation immediately. Overall, there was a good level of understandability.

Two respondents said that the heuristics helped them learn about accessibility at the same time. Five respondents reported needing time to understand the heuristics before using them:

> It initially took some time to grasp the list of heuristics, but I got to the point well; after that, it was easy to use it to assess online content.

For memorability, we asked, 'Evaluate how the heuristic list supports memorability. Imagine you are working for an organisation in the summer. Your job is to improve the accessibility of online content, and you want to start the task by evaluating existing online content, although the heuristic list is not available. What things on the heuristic list could help bring things to mind? Is there something missing that could make it easier to remember?' Twelve respondents recommended visual additions to the heuristic list presentation (e.g., use of colour coding by theme, icons in the titles or a symmetric layout). No one suggested improvements to the content of the heuristics:

> I think the list is made easy to remember when things are broken down by theme. A more visual look could help with memorability.

These results are in line with those of the reflection papers, as all suggested improvements related to layout. In this study, we scoped the development to concern only the content of the heuristics, not the layout.

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4.5 Proposed heuristics for accessible online text production

As a result of the two design iterations and as an answer to our research question, we proposed a total of 15 heuristics to improve accessible online text production. The heuristics are meant for content creators in public organisations to achieve or enable text accessibility for users with disabilities on a website and thus foster the principle of equal access for all.

The heuristics may also be used as a self-assessment tool for the same purpose. The heuristics are a combination of three categories: text formatting, text structure and text content. The instructions and explanations of the proposed heuristics are presented in Table 4.

Heur.	*Instructions*	*Explanation*	*Category*
H1	Emphasise verbally the important points you want to make. You may also use bolding or colours for emphasis, but do not use bolding to indicate titles.	The reader may only listen to your written text, in which case the emphasis or use of colours is ignored.	Formatting
H2	Use font sizes 18-26 pt. for online content and 22-26 pt. for headings, depending on the heading level.	Larger font sizes improve online readability.	Formatting
H3	Favour sans serif fonts, such as Verdana or Arial.	A sans serif font is simple, so it is clear and easy to read online. Verdana is one of the most popular and aesthetically pleasing fonts designed for on-screen viewing. Arial is slightly faster to read.	Formatting
H4	When you list things, use bullets or numbers. Try to avoid using multi-level lists.	By using bullets for main topics, you help readers scan your content and identify key areas. Multi-level lists can be confusing.	Formatting

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Heur.	*Instructions*	*Explanation*	*Category*
H5	Make the text airy. Adjust the line and paragraph spacing.	Readability increases if the line spacing is 1.5 and the paragraph spacing is twice the font size.	Formatting
H6	Align text to the left.	Text aligned to the left margin makes it easier to find the start of the next line.	Formatting
H7	Pay attention to the contrast between the text and the background.	To improve readability, you may use light tones of warm colours for the background.	Formatting
H8	Use headings (H1, H2, etc.) consistently. Avoid sub-sub-headings (e.g., 1.1.1.1).	Do not use headings to increase just font size, as headings are meant to divide content into meaningful sections. Headings are important for screen reader users to navigate a page according to its headings.	Structuring
H9	When you add images using information, explain their message in the textual content. This way, the screen reader user gets the same information, too.	If the image is not described in the text content, you can describe it in about 100 character-long alt text (in image properties). When a screen reader finds an image, it reads out the content of the alt tag.	Structuring
H10	Separate links from other content with underlined blue colour, and use text that properly describes where the link will go.	Name links according to the action that will occur or the place or name of the website to which the user will be taken (e.g., 'Go to calendar').	Structuring
H11	Use clear and simple language.	Use common everyday words and avoid the use of jargon whenever possible.	Content

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Heur.	*Instructions*	*Explanation*	*Category*
H12	Provide the full meanings of abbreviations and acronyms at their first use.	Abbreviations and acronyms should be defined in full. The exception is established abbreviations, which may not even be recognised when written out (e.g., DVD).	Content
H13	Provide the most relevant information first. For long texts, provide a short summary of the content at the beginning.	The content is easier to perceive when the most important information is placed on the top of the page.	Content
H14	Prefer short sentences and avoid complicated sentence constructions.	Short sentences help readers understand the content better. Express one idea in one sentence.	Content
H15	Use *you* when addressing the reader.	This way, readers feel that the text is speaking to them.	Content

Table 4. Online text accessibility heuristics

Formatting text

Our proposal contains seven heuristics (H1-H7) related to text formatting.

(H1)*:* It is important to consider that the reader may focus only on the written text, in which case emphasising with text bolding, using italics or using colours is irrelevant. It should also be noted that using only bolding to indicate a title does not make it a title structurally. Pointing out important information verbally benefits people with limited colour vision, people who use Braille or screen magnifiers and people who have difficulties understanding cues or messages between colour and text (W3C, 2018).

(H2): According to a study by Rello et al. (2016), larger font sizes, such as 18-26 pt, help improve readability, overall, when reading from the screen, and this is especially true for people with dyslexia or people with a lower level of visual impairments (W3C, 2018). It should also be noted that different fonts of the same size may look different in their actual size. **(H3):** Rello and Baeza-Yates (2013) showed in their study that different fonts have pros and cons, so recommending one is difficult. According to their

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research, Arial, for example, is faster to read, but Verdana is more pleasant looking and popular (Rello & Baeza-Yates, 2013). As a general rule, it is recommended to use an endless font (i.e., sans serif or grotesque fonts, such as Verdana and Arial, which both significantly improve readability for people with dyslexia (Rello & Baeza-Yates, 2013).

(H4): Using bullets for main topics or for the main information helps readers scan the content and identify key areas. However, multi-level lists can be confusing and are therefore not recommended. Chen et al. (2015) reported that using bullets to present important information contributes to the perception of content and the comprehension of important information, thus supporting learning, especially for people with dyslexia.

(H5): Rello et al. (2012) considered the *airiness* of the text (i.e., line spacing, spacing of text paragraphs and spacing of letters and words) to be more important than the choice of fonts. As a solution, readability will improve if the line spacing is at least 1.5 and the paragraph spacing is twice the font size. Chisnell et al. (2006) recommended avoiding overcompressing content.

(H6): According to plain language printing instructions, instead of justified text, only left-aligned text should be used. Left-aligned text helps readers perceive the transition from one line to another (European Agency for Special Need and Inclusive Education, 2015; Plainlanguage.gov, 2011).

(H7): As a result of the first design iteration, guidance regarding the appropriate background colour was needed in addition to the proposed heuristics. According to Rello and Bigham (2017), the use of light tones of warm colours for the background improves readability for people with dyslexia.

Structuring the text

Our proposal contains three heuristics (H8-H10) related to text structure.

(H8): The PSs placed the major quantitative emphasis on issues related to navigation, as well as on the title structure of the text. Heading levels should be used sequentially and logically to facilitate navigation. Headings should not be used only to increase font size, as headings are meant to divide content into meaningful sections. Sequentially and logically used headings benefit people with cognitive disabilities, limited short-term

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memory, visual disabilities and severe mobility impairments, as well as people who use audio for navigation (W3C, 2018).

(H9): The PSs placed the greatest quantitative emphasis on issues related to the alternative text. According to the WCAG, alt text should only be given to non-text elements, such as images, charts, videos and audios, if they are used to share particular information (W3C, 2018). In the HTML structure, the recommended length for alternative text is about 100 characters maximum (W3C, 2018). This poses a challenge for content creators if there is much information in an image. Therefore, we recommend that all information be written in the body text. If images or other elements are used alone without explanatory texts, they should be described with alternative texts using about 100 characters. Repeating the same information in the text and alt text is unnecessary. The information presented should be the same, with or without the capability to interpret images. The use of alternative text is identified to benefit people with difficulties in perceiving visual information, understanding the meaning of images or perceiving or understanding audio information, as well as people who use Braille (W3C, 2018).

(H10): The PSs strongly emphasise the importance of naming links in the text; links should be presented with an action word, such as 'Go to calendar', which tells readers where the link leads. We also recommend using the colour blue and underlining to separate the link from the text because these have the strongest perceived affordance of clickability (Nielsen, 2004).

Content of the text

Our proposal contains five heuristics (H11-H15) related to formulating content.

(H11): The choice of the appropriate language for the target group includes the idea that the author always keeps in mind who is reading their text (Union, 2012). The requirement for clear and simple language is also familiar in usability studies, in which clear and simple language has been found to promote comprehensibility, including in specialised fields (Richardson et al., 2017). Clear and simple language also means avoiding professional slang or jargon, as it is often difficult for outsiders and the public to understand (Union, 2012). The PSs encourage the use of the simplest possible language appropriate to the document. This means the use of familiar, everyday words and avoiding expressions whose meaning cannot be inferred from the meaning of individual words. For texts addressed to the public (i.e., wide heterogeneous groups), we suggest

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using common everyday words and avoiding the use of jargon whenever possible to benefit especially those people who have difficulty comprehending and interpreting written language (Plainlanguage.gov, 2011; W3C, 2018).

(H12): Abbreviations and acronyms should be written in full. The exception is established abbreviations, which may not even be recognised when written out (e.g., DVD = digital video disk). Abbreviations should be used with caution and defined in full for at least their first mention (European Agency for Special Needs and Inclusive Education 2015; Union 2012). This benefits people who have difficulties decoding words or using context to aid understanding, people with limited memory and people who use screen magnifiers (W3C, 2018).

(H13): ICT4IAL recommends adding short summaries of the content or paragraph (European Agency for Special Needs and Inclusive Education 2015) but does not indicate the place of the summary. We suggest providing a summary at the beginning of the text, as it gives readers an idea of what the following text contains (Union, 2012).

(H14): Short sentences, in which one important thing is expressed per sentence, help ensure that the text does not become too complicated (Plainlanguage.gov, 2011). This is vital for online content, as short sentences make it easier to find the main points of the sentences. Short sentences help readers better understand the content.

(H15): Addressing text to the reader, the you-form or the active voice is one way to increase text comprehensibility (Plainlanguage.gov, 2011). As a result, readers feel that the text is speaking to them.

5 Discussion and concluding remarks

There is an urgent need for clearer and easier-to-use guidance for accessible text production in public organisations. Content creators do not have appropriate accessibility guidance in use for text production, despite reading remaining one of the most common ways to perceive information on the web (Rello et al., 2016). Existing accessibility guidelines are often scoped to web accessibility and thus provide appropriate guidance mainly to webmasters and web developers, whose main responsibility is the development and maintenance of websites. Content creators need to adopt these practices, which may be confusing or difficult. However, textual content is one of the most important channels for sharing information (Kalender et al., 2018). In this study, we

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therefore provided improvements to accessibility guidance for textual online content by creating a proposal for accessibility heuristics for text production.

We extracted factors that improve text accessibility from the PSs (see Table 3). The PSs contained relatively few instructions related to text issues (PS1: four, PS2: two, PS3: two, PS4: four, PS5: five, PS6: eight, PS7: eleven). From this selected set, WCAG 2.1 (PS6) and ICT4IAL (PS7) provided the greatest number of instructions. Compared with the proposed heuristics, WCAG 2.1 does not provide detailed instructions relating to (1) font size (see H2), (2) font selection (see H3), (3) use of bullets (see H4), (4) text alignment (see H6), (5) order of content by importance (see H13) and (6) summary provision of content (see H13), but these factors significantly improve readability and support the learning of people with dyslexia or those with lower levels of visual impairments (Chen et al., 2015; Rello et al., 2016; Rello & Baeza-Yates, 2013). Some of the instructions in the PSs are repetitive, but many have been provided only once. As an example, WCAG 2.1 provides very detailed instructions for letter and word spacing in the system preferences, which are difficult to implement for content creators because of access to these preferences. In the workshop, the participants used the Moodle text editor with basic text editing features that are similar to those of other content management systems in public organisations. However, ICT4IAL does not provide any instructions for text spacing. We therefore ended up with a solution that is practicable for content creators in their context. The comparison of ICT4IAL with other PSs shows that it differs only in two instructions—the provision of precise line spacing and the instruction on information order. Based on the PSs, ICT4IAL is the most comprehensive, but it lacks detailed practical guidance on how and why to implement it, which emerged as a crucial need of the workshop participants to which the presented heuristics responded.

Our proposed heuristics differ from the PSs in their provided contributions. First, the result of the literature review divided the proposed heuristics into categories: *formatting*, *structure* and *content.* The workshop participants, as well as the content creators, reported that the categorisation helped them perceive and understand the structure of the heuristics. It also aided them in focusing on particular areas for which they needed help. Second, the proposed heuristics were derived and formulated based on the PSs, supplements, the results of the design and evaluation workshop, and the results of the evaluation made with content creators. Unlike the guidance provided by the PSs, the proposed heuristics were designed to solve the difficulties that content creators in the public sector may face when producing online text. Many of the related studies contributed guidelines for improving the readability or accessibility of online text reporting guidelines that considered the needs of dyslexics (Li et al., 2019; Miniukovich et al., 2017; Rello et al., 2012). The proposed heuristics aim to improve text accessibility for a

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wide scope of users' needs. Therefore, beyond the needs of dyslexic heuristics, they also covered the needs of people with difficulties in understanding content or cues (cf., H15; H9; H1), people with limited memory (cf., H12) or those with difficulties in perceiving visual information (cf., H1; H9; H12).

The effects of the proposed heuristics are based on evidence from the literature. Implementing these heuristics makes text easier to perceive and written language easier to navigate, read, interpret and understand; heuristics help make the interaction more usable. However, the implementation of the heuristics and their effects on improved usability are not discussed in this paper and require further research.

In terms of significance to practice, existing guidelines are confusing, difficult to implement and too technical; they are inappropriate for most content creators. Based on the presented results, the proposed heuristics are clear, easy to understand and useful. When formulating the heuristics, we ensured that they are easy to use (i.e., they are clear and simple and thus immediately usable as such). Unlike using the WCAG, applying these heuristics does not require knowledge of HTML. The heuristics respond to the need that emerged as a result of the legal obligations imposed on the accessibility of websites in public sector bodies. It should be noted that the heuristics presented in this paper do not meet all legal obligations regarding accessibility, as only the accessibility of textual online content was addressed here. However, it should be noted that legislation, for example, the EU directive, recommends following the WCAG middle-level AA, ignoring all AAA-level guidance, even if it has a significant impact on understanding words and phrases and on decoding words (W3C, 2018). In the AAA level, the WCAG give guidance for unusual words, abbreviations and reading, which all are considered in the proposed heuristics as crucial points when creating accessible text content.

This study also has implications for design knowledge. In the development process, we involved possible users in two rounds: first, in the workshop for developing the heuristics and, second, in the ex ante evaluation (Sonnenberg & vom Brocke, 2012).We assessed and re-formulated the heuristics with university master's-level students who were *on the crest of a wave* of their studies in technical communication, meaning that they were recently introduced to the topic. They also had some experience in website design and content creation, and almost everyone had work experience in companies or public sector organisations. Therefore, the students were regarded as intermediate content creators. The focus in the workshop was on the content and formulation of the heuristics, their usability and their utility.

Second, we involved content creators to assess feasibility as an ex post evaluation (Sonnenberg & vom Brocke, 2012). The participants had different years of work ex-

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perience in content creation, from 4 years to 15 years. Both sessions gained valuable contributions in tackling domain-specific concerns.

As a methodological contribution, involving possible users in the development and evaluation of the heuristics from two groups with different perspectives; students who evaluated learnability, utility, memorability, flawlessness and consistency of the heuristics; and content creators who evaluated importance, feasibility and utility to practice, can improve robustness because the formulation of the heuristics and domain-specific concerns are already considered in the development process. Moreover, we found it important that solutions should be evaluated not only by their means of effectiveness but also by their feasibility; they are formulated so that they respond to the problem in the problem's context.

5.1 Limitations and future research

This study has its limitations. Our PSs consisted only of research found via Google Scholar with a certain search term and string. The use of alternatives in search terms and various databases may provide a broader knowledge base. However, to supplement the search results, we added WCAG 2.1 and ICT4IAL guidelines to the PSs. Although the PSs contained only seven studies, we believe that they represented the best practices in the field, as these studies contained 10 separate sets of guidelines for web accessibility, including major guidelines, such as the WCAG, Section 508 Web Standards and IBM web accessibility heuristics, amongst others (see Table 2). We scoped voice and video content and mobile applications beyond the heuristics. However, it should be noted that the first means to improve the accessibility of audio and video formats is to provide text alternatives and captions that require text production (European Agency for Special Needs and Inclusive Education 2015; W3C 2018). The proposed heuristics are general in nature and do not consider different text genres. The heuristics are designed for Western writing systems, which means that they need to be modified for other writing systems.

We identified emerging problems from the iterations for future research. The workshop participants reported on the requirements for the presentation and layout of the heuristics that we scoped out from this study. As a preliminary solution, the workshop participants suggested features for the layout (e.g., icons, colours and mnemonics) to improve their learning, memorability and motivation to use the heuristics. How the implementation of the proposed heuristics affects usability also requires empirical research. This study serves as a starting point for the future development and testing of the proposed heuristics.

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Implementation of the Online Text Accessibility Heuristics

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Abstract

A significant proportion of online content is still in textual form, and more and more people are involved in editing and producing textual content. Heuristics can help content creators ensure that the text content they create is accessible. Heuristics are relatively easy to use, clear, and do not necessarily require any prerequisites. However, using heuristics or guidelines in the first place during the writing process can be mentally demanding because the writer has to memorise the knowledge about the audience, set a goal, organise the text, translate ideas into language, evaluate, and revise the text at the same time when using external guidance. To make the use of online text accessibility heuristics more natural and efficient during the writing process, they should be presented in an order that fits the writing process. In this chapter, we align an online text accessibility heuristics set with the cognitive process theory of writing. As a result, we propose an implementation model for online text accessibility heuristics.

Keywords: text accessibility, accessibility heuristics, heuristics, text accessibility implementation, implementation model

1. INTRODUCTION

The digitisation of everyday life has led to an increase in users needing accessible content on websites, mobile applications, and digital services. Despite the increasing amount of audio-visual content, a considerable proportion of online content is still in textual form (Kalender et al., 2018), and to convey meaning, texts and linguistic elements have a great responsibility (Isohella & Nuopponen, 2016, p. 226). Furthermore, the use of assistive technology, such as screen readers, makes interaction with text content a listening activity (Babu et al., 2010). Therefore, the text should be produced in such a form that it supports not only reading but also listening activities. Writing and text production are also essential in the digital age, and online written interactions in contemporary organisations rely on writing (Fayard & Metiu, 2012). Fayard and Metiu (2012) conceptualise writing not only as a technology but primarily as a fundamental mode of communication: we are writing and reading more than ever. Hilbert (2014, p. 138) found in his large empirical inventory that 'the proportional share of alphanumeric text is larger in the digital "multimedia age" than it has been at the end of the analog age.'

From the perspective of content production, the online text accessibility heuristics by Mäkipää and Isohella (in press) provide hands-on guidance for accessible text production. They are meant for people who especially create text content for the web to achieve or allow text accessibility. The heuristics may also be used as a self-assessment tool for the same purpose. The creation of the heuristics addressed problems relating to the technicality and understandability encountered by content creators, especially people who are not webmasters or web developers but who need to edit and produce web content (Henka & Zimmermann, 2014). Even though the heuristics are meant for text content creation, they do not consider the writing process itself. The writing process consists of several phases and elements (Flower & Hayes, 1981), and the use of external guidelines during the writing process can increase the writer's cognitive load, which makes guidelines difficult to implement. We need to remember that people who create text content, that is, writers, are also humans, which means that heuristics themselves should be accessible (Iivari et al., 2020).

In this chapter, therefore, we address the problem of how heuristics should be implemented to support the writing process in content creation. To improve the accessible use of heuristics, we align the online text accessibility heuristics by Mäkipää and Isohella (in press) to the cognitive process theory of writing by Flower and Hayes (1981). We propose an implementation model to make the use of heuristics more natural and efficient during the writing process.

2. BACKGROUND OF TEXT ACCESSIBILITY IN WEB CONTEXT

The well-known ISO standard (ISO 9241–11:2018), to which the European Union (EU) legislation also refers, defines accessibility as the "extent to which products, systems, services, environments, and facilities can be used by people from a population with the widest range of user needs, characteristics, and capabilities to achieve identified goals in identified contexts of use" (International Organization for Standardization, 2018). Overall, digital products on the web, for example, websites and mobile applications, are composed of content, presentational style, functionality, and interactional style (Hassenzahl, 2004). The content on the web generally refers to the information presented on a web page or web application, including texts, images, sounds, and code or markup that defines the structure, presentation, etc. (Web Accessibility Initiative, 2016).

In this chapter, we focus on how texts should be presented to provide access to the information that the writer wants to convey. Therefore, with respect to human rights, the content presented in texts should accommodate a population with the widest range of needs and disabilities (World Health Organization, 2002). The United Nations Convention on the Rights of Persons with Disabilities (CRPD) defines people with disabilities as "those who have 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, 2006).

However, accessible texts should be applicable to everyone, not only people with disabilities (Yesilada et al., 2015). Although the scope of accessibility and its interconnection with usability have been hard to define (Giraud et al., 2018; Leuthold et al., 2008; Link et al., 2006; Martins et al., 2017; Ruiz et al., 2011; Vollenwyder et al., 2019), usability to all could also be enhanced by improving accessibility (Web Accessibility Initiative, 2016). For example, adjustments to accessibility that reduce cognitive load improve usability, such as effectiveness, efficiency, and satisfaction (Giraud et al., 2018). Thus, the purpose of making text content accessible is to primarily benefit users with disabilities to access the information while improving understandability, memorability, efficiency, and overall satisfaction.

In the context of text accessibility, assistive technologies (AT) play a significant role, as they provide an alternative method to perceive the information. The most widely adopted AT for reading digital texts for individuals who are blind or visually impaired is text-to-speech AT, often called screen readers or read-aloud readers (Ferres et al., 2013). Screen readers are also used by people with physical, cognitive, or literacy disabilities to independently read an online text (Newman et al., 2017).

The use of screen readers makes reading a listening activity (Babu et al., 2010; Dim et al., 2018). Screen readers read a web page aloud from the top left to the bottom right (Babu et al., 2010) which makes the navigation behaviour of blind users completely different from that of sighted users, often extremely difficult (Harper & Bechhofer, 2007; Leuthold et al., 2008). This means that blind users must form their mental model of the structure based on linearly presented audible information about navigation items and other audible cues from the visual context (Leuthold et al., 2008). For sighted people, visualisation of text, such as text size, colours, and other visual formatting, may convey meaning and provide cues about web page structure and intended navigation space. However, when listening to a text, these meanings and cues cannot be perceived, which poses challenges in providing the same meaning in the content of the text. Moreover, the information presented in non-textual elements, such as images and graphs, should also be presented alternatively in text so that the AT can interpret the information in audio format (W3C, 2018). However, for people with cognitive disabilities, the factors that cause difficulties in cognition, such as cognitive load, remembering task-related steps, or understanding terminology, are more relevant than difficulties in reading from the screen or perceiving other visual information, such as icons (Sayago & Blat, 2010).

As a response to the inclusion of people with different needs, the online text accessibility heuristics by Mäkipää and Isohella (in press), to which we will refer as the heuristics, aim to improve text accessibility for a wider scope of users' needs. The heuristics are meant for people who create text content for the web to achieve or allow text accessibility for users with disabilities. The heuristics may also be used as a self-assessment tool for the same purpose. Many prior studies have provided guidelines for improving the readability or accessibility of online text reporting guidelines that consider the needs of people with dyslexia (c.f. Li et al., 2019; Miniukovich et al., 2017; Rello et al., 2012). Therefore, beyond the needs of people with dyslexia, these heuristics also cover the needs of people with difficulties in understanding content or cues, people with limited memory, or those with difficulties in perceiving visual information.

The heuristics are a combination of three categories: text formatting, text structure, and text content. The aim of the categorisation is to help the person using them perceive and understand the structure of the heuristics and to focus on areas in which help is needed. The heuristics are formulated and tested empirically with content creators in public organisations. According to the study by Mäkipää and Isohella (in press), the heuristics are clear, easy to understand, and useful. However, it should be noted that the heuristics do not meet all legal obligations regarding accessibility, as only the accessibility of textual online content is addressed. Moreover, heuristics can be defined as a set of principles that guide our actions towards a procedure, new ideas, and results (The Helsinki Term Bank for the Arts and Sciences, 2021). This means that heuristic principles should not be taken as rigorous prescriptions, they rather "give useful recommendations and hints but never require exactly one special solution" (Gadanne, 2006).

The heuristics contain seven items (H1–H7) related to text formatting, three items (H8–H10) related to text structure, and five items (H11–H15) related to formulating content. However, the heuristics do not address the writing process, which may influence the implementor's cognitive load. Inspired by the cognitive process theory of writing by Flower and Hayes. (1981), we next discuss the order in which the heuristics should be implemented to support the writing process.

3. IMPLEMENTING THE TEXT ACCESSIBILITY HEURISTICS

According to Flower and Hayes (1981), writing as an act contains three major elements: (1) the task environment, (2) the writer's long-term memory, and (3) the writing process. The task environment includes, for example, rhetorical decisions and plans for reaching the audience, which affects the process of organising ideas at all levels. The writer also reviews the text that s/he has produced so far for the task.

The writer's long-term memory contains knowledge about the audience, as well as the topic and writing plans. Knowledge about the audience and plans for reaching the audience are guided by goal setting in the planning process as a part of the writing process (Flower & Hayes, 1981). The writing process contains three basic processes: (1) planning, (2) translating, and (3) reviewing.

The planning process includes organising and ordering the text and it refers to the writer's internal formulation of represented knowledge or information that s/he is about to write. This process consists of idea generation, when the writer reflects on his or her knowledge (long-term memory) about the topic, audience, and prior writing plans to generate ideas. This may also include the use of outside resources, such as books. Translating refers to the process by which the writer puts his or her ideas into visible language. In the reviewing process, the writer reads and evaluates what s/he has written so far and the revision of the text. The reviewing process has a cycle back to the planning and translating processes, which means that if the writer is not satisfied with the written text, s/he restarts or reconsiders the planning and translating process again (Flower & Hayes, 1981) (see Figure 1 for areas marked with a dashed line).

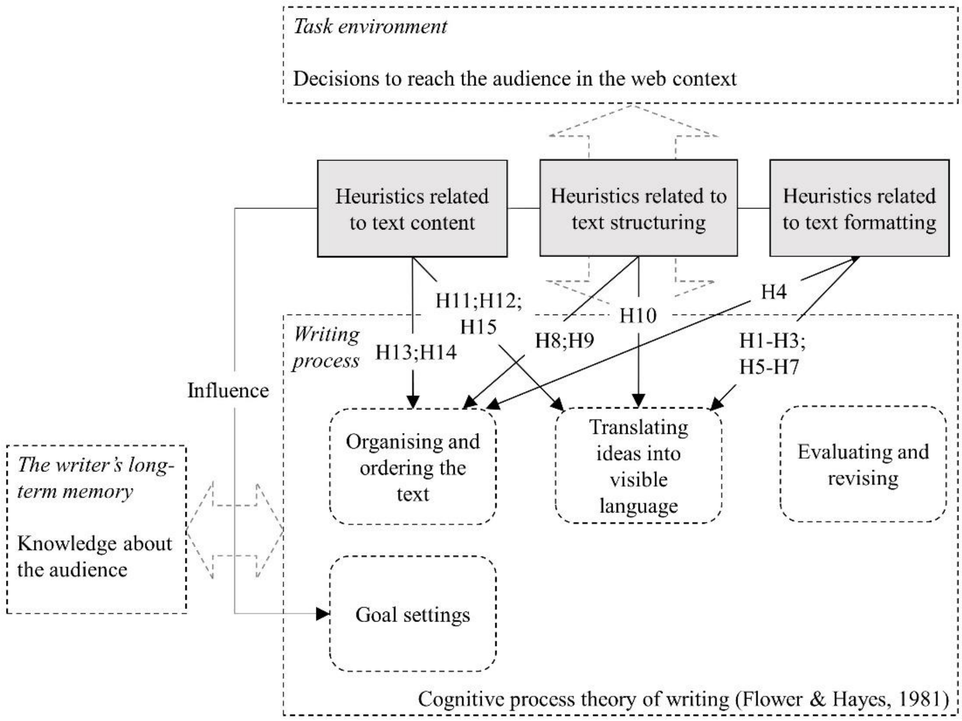

Figure 1. Online text accessibility heuristics implementation model

To integrate the online text accessibility heuristics (Mäkipää & Isohella, in press) into the writing process and support the writer's plans to reach the audience, we compared and aligned the heuristics to the elements of writing in the cognitive process theory of writing by Flower and Hayes (1981) (see Figure 1).

We posited the implementation of the heuristics between the *writing process* and the *task environment*. This means that the writer considers the heuristics when making decisions to reach the audience in the web context. Therefore, the heuristics related to text formatting, text structure, and text content can be implemented during the planning process, including the knowledge organisation, or during the translating process. Moreover, the use of the heuristics influences the writer's knowledge about the overall needs for accessibility of the audience; hence, the use of the heuristics also influences the writer's goal settings.

Instead of following the original sequential order, we propose that the writer should first implement the heuristics related to the content, followed by the heuristics related to structuring, and lastly, the heuristics related to formatting. To fit this order to the writing process, we propose implementing the heuristics when the writer is about to organise and order the text and then translate the ideas into visible language.

In what follows, we explain the heuristics one by one and discuss why this order makes their use more natural and efficient in the writing process and how it affects the writer's cognitive load, thus the accessibility of the heuristics. The letter H refers to the word heuristics, and the number attached to it refers to the heuristic number in the original version. We suggest implementing the heuristics in the following order:

1. Organising and ordering the text (H13, H14, H8, H9, H4)
2. Translating ideas into visible language (H11, H12, H15, H10, H1, H2, H3, H5, H6, H7)

During the organisation and ordering of the text, we suggest first implementing heuristics H13 and H14 for the formulation of the content of the text, because in this phase, the writer goes through the process of identifying important ideas, ordering the text, and identifying presentational style (Flower & Hayes, 1981).

H13: "Provide the most relevant information first. For long texts, provide a short summary of the content at the beginning – The content is easier to perceive when the most important information is placed on the top of the page". Providing a summary at the beginning of the text gives readers an idea of what the following text contains. It helps them get an idea of the upcoming topic, which reduces cognitive load (Union, 2012). Similarly, this helps the writer clarify the generated idea of an upcoming text.

H14: "Prefer short sentences and avoid complicated sentence constructions – Short sentences help readers understand the content better. Express one idea in one sentence". Writing short sentences and expressing one important thing per sentence keeps the text simple, thus helping readers to better understand the content. (Plainlanguage.gov, 2011). This heuristic tells the writer what the kind of sentence should be. Therefore, it should be implemented when the writer is identifying an appropriate presentational style for the audience to avoid rewriting in a later phase.

Next, H8 and H9 should be implemented for structuring the text because these heuristics provide instructional information on how the factors that influence accessibility should be addressed in the structure of the text.

H8: "Use headings (H1, H2, etc.) consistently. Avoid sub-sub-headings (e.g., 1.1.1.1) – Do not use headings to just increase font size, as headings are meant to divide content into meaningful sections. Headings are important for screen reader users to navigate a page according to its headings". Sequentially and logically used headings benefit people with cognitive disabilities, limited short-term memory, visual disabilities, and severe mobility impairment, as well as people who use audio for navigation (W3C, 2018). When organising the text, the titles of the text (heading levels) should be used sequentially and logically to facilitate navigation. According to the presentational style, in online text, headings should not be used to only increase font size, as headings are meant to divide content into meaningful sections.

H9: "When you add images using information, explain their message in the textual content. This way, the screen reader user gets the same information, too – If the image is not described in the text content, you can describe it in about 100 character-long alt text (in image properties). The use of alternative texts benefits people with difficulties in perceiving visual information, understanding the meaning of images, or perceiving or understanding audio information, as well as people who use braille (W3C, 2018). When a screen reader finds an image, it reads out the content of the alt tag". If non-text elements, such as images, charts, videos, audios, or other elements, are used alone without explanatory texts, they should be described with alternative texts using about 100 characters. However, as the limited number of characteristics may cause challenges in conveying the message, the heuristics recommend providing all the information in the body text. Further, repeating the same information in the text and alt text is unnecessary. Therefore, when organising text and images, it should be considered that the information presented is the same, with or without the capability to interpret images.

Then, as a final heuristic for organising and ordering the text**,** H4 should be implemented to format the text. H4 refers to presentational style.

H4: "When you list things, use bullets or numbers. Try to avoid using multi-level lists – By using bullets for main topics, you help readers scan your content and identify key areas. Multi-level lists can be confusing". If the information, ideas, or presentational style contains things that need to be listed, bullets or numbers should be used for the main topics or for the main information. Bullets or numbers help readers scan the content, identify key areas, and contribute to the perception of content and the comprehension of important information, thus supporting learning, especially for people with dyslexia (Chen et al., 2015).

In the next process, in which the writer is about to translate ideas into a visible language (Flower & Hayes, 1981), we suggest implementing heuristics H11, H12, and H15 for formulating the content of the text.

H11: "Use clear and simple language - Use common everyday words and avoid the use of jargon whenever possible". The writer should always keep in mind who is reading his/her text. For texts addressed to wide, heterogeneous groups, the heuristics suggest using common everyday words and avoiding the use of jargon whenever possible, avoiding expressions whose meaning cannot be inferred from the meaning of individual words. The use of clear and simplest possible language appropriate benefits especially those people who have difficulty comprehending and interpreting written language (Plainlanguage.gov, 2011; Richardson et al., 2017; W3C, 2018). To reduce cognitive load, designers should, for example, avoid using difficult terminology or jargon in the text content, as this may significantly increase not only understanding but also the motivation to use information (Sayago & Blat, 2010).

H12: "Provide the full meanings of abbreviations and acronyms at their first use - Abbreviations and acronyms should be defined in full. The exception is established abbreviations, which may not even be recognised when written out (e.g., DVD)". Abbreviations and acronyms should be used with caution and written in full for the first time. (European Agency for Special Needs and Inclusive Education, 2015; Union, 2012). This benefits people who have difficulties decoding words or people with limited memory, and people who use screen magnifiers (W3C, 2018).

H15: "Use *you* when addressing the reader - This way, readers feel that the text is speaking to them". To improve comprehensibility in cases where the writer wants to address the text directly to the reader, the use of a you-form or active voice makes the reader feel that the text is meant for him/her (Plainlanguage.gov, 2011).

Next, we suggest implementing H10, which relates to structuring the text. In our opinion, H10, which refers to the formulation of links, should be implemented during the translation of ideas into visible language because they can be presented in many visible forms.

H10: "Separate links from other content with underlined blue colour and use text that properly describes where the link will go - Name links according to the action that will occur or the place or name of the website to which the user will be taken (e.g., 'Go to calendar')". If the text contains links, they should be presented with an action word, using the colour blue and underlining to separate the link from the body text. According to Nielsen (2004), this formulation has the strongest perceived affordance of clickability. Moreover, the writer needs to fit the words used in the links into the body text to make the reading fluent.

Lastly, when translating ideas into a visible language, H1–H3 and H5–H7 should be implemented for formatting the text visually.

H1: "Emphasise verbally the important points you want to make. You may also use bolding or colours for emphasis, but do not use bolding to indicate titles - The reader may only listen to your written text, in which case the emphasis or use of colours is ignored". Pointing out important information verbally benefits people with limited colour vision, people who use braille or screen magnifiers, and people who have difficulties understanding cues or messages between colour and text (W3C, 2018). As the reader may only listen to the written text with AT, text bolding, italics, and text colours become irrelevant in these cases. Moreover, the writer should note that using only bolding to indicate a title does not make it structurally a title. However, the heuristics do not prohibit the use of visual formalisations in the text but emphasise that they should not be the only means of demonstrating information.

H2: "Use font sizes 18–26 pt. for online content and 22–26 pt. for headings, depending on the heading level - Larger font sizes improve online readability". The text should be written in larger font sizes, such as 18–26 pt, depending on the heading level. This improves overall readability when reading from the screen, especially for people with dyslexia (Rello et al., 2016) or people with a lower level of visual impairments (Rello et al., 2016; W3C, 2018).

H3: "Favour sans serif fonts, such as Verdana or Arial - A sans serif font is simple, so it is clear and easy to read online. Verdana is one of the most popular and aesthetically pleasing fonts designed for on-screen viewing. Arial is slightly faster to read". When selecting the font for the text, a general rule is recommending using an endless font (i.e., sans serif or grotesque fonts, such as Verdana and Arial, which both significantly improve readability for people with dyslexia; (Rello & Baeza-Yates, 2013). According to Rello and Baeza-Yates (2013), different fonts have pros and cons, so recommending one is difficult. Arial, for example, is faster to read, but Verdana is more pleasant looking and popular (Rello & Baeza-Yates, 2013).

H5: "Make the text airy. Adjust the line and paragraph spacing - Readability increases if the line spacing is 1.5 and the paragraph spacing is twice the font size". Formatting, such as line spacing, spacing of text paragraphs, and spacing of letters and words—that is, the *airiness* of the text—could be even more important than the choice of fonts (Rello et al., 2012). Readability will improve if line spacing is at least 1.5, and paragraph spacing is two times the font size. Therefore, overcompressing the content is not recommended (Chisnell et al., 2006).

H6: "Align text to the left - Text aligned to the left margin makes it easier to find the start of the next line". To help readers perceive the transition from one line to another, the text content should be aligned with the left margin instead of distributing the text between both margins. (European Agency for Special Needs and Inclusive Education, 2015; Plainlanguage.gov, 2011).

H7: "Pay attention to the contrast between the text and the background - To improve readability, you may use light tones of warm colours for the background". According to Rello and Bigham, (2017), the use of light tones of warm colours for the background improves readability for people with dyslexia.

The third process included in the writing process, *evaluating and revising,* is not aligned straight to the implementation of the heuristics, as this phase refers to the process in which the writer reads and evaluates what s/he has written and revises the text by moving back to planning and translating processes. However, in cases where the writer starts to evaluate previously written text against the heuristics, the whole writing process may start from the evaluating and revising process.

4. SUMMARY AND CONCLUSION

In this chapter, we discussed how heuristics for accessible online text could be implemented to support the writing process. The heuristics by Mäkipää and Isohella (in press) contain 15 hands-on principles in three categories: text formatting, text structure, and text content to improve the production of accessible online text in the web context. The implementation of the heuristics makes the text content easier to perceive and the written language easier to navigate, read, interpret, and understand, thus affecting the usability. However, the heuristics do not consider the writing process, during which they can be mentally demanding to implement.

By comparing and aligning the heuristics to Flower and Hayes' (1981) cognitive process theory of writing, we created an implementation model for online text accessibility for people who write or evaluate text content for the web to achieve or allow text accessibility.

Approaches to accessible online text content lack empirical investigation. There are various guidelines and heuristics, but it seems essential to better fit them into practice by recognising the writing, for example, content creation process. We believe that our implementation model makes the use of the heuristics more natural and efficient during the writing process, as they are fitted into phases when the writer is about to organise and order the text and translate ideas into visible language.

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