SHAPES

Smart and **H**ealthy **A**geing through **P**eople **E**ngaging in supporting **S**ystems

D5.1 – SHAPES User Experience Design and Guidelines

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Table 1 Revision History

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Table of Contributors

Table 2 Deliverable Contributors

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Table of Contents	
1. Introduction	Anabela G. Silva, Nelson P. Rocha
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3. User experience	Anabela G. Silva, Rita Tavares, Nelson P. Rocha
4. User interface design	Margarida Almeida, Telmo Silva, Rita Tavares, Anabela G. Silva, Nelson P. Rocha
5. Usability inspection methods	Anabela G. Silva, Nelson P. Rocha
6. Usability Assessment involving users	Anabela G. Silva, Óscar Ribeiro, Nelson P. Rocha
7. User Interface Design and Usability Assessment of SHAPES platform and Digital Solutions	Margarida Almeida, Telmo Silva, Rita Tavares, Anabela G. Silva, Nelson P. Rocha

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8. Consensus Generating Procedure on User Interface Design Guidelines and Usability Assessment	Anabela G. Silva, Nelson P. Rocha
9. Full revision of deliverable	Rita Tavares, Óscar Ribeiro, Gonçalo Santinha

Table of Acronyms and Abbreviations

Table 3 Acronyms and Abbreviations

Acronym	Full Term
AELTD	Access Earth Limited
EDGE	EDGENEERING Lda
ICOM	Intracom SA Telecom Solutions
ISO	International Organization for Standardization
PAL	PAL Robotics SL
SCIFY	Science for You – Epistimi Gia Sena Astiki Mi Kerdoskopiki Etairia
UAVR	Universidade de Aveiro
UNRF	University of Nicosia Research Foundation
UX	User Experience
VICOM	VICOMTECH
WFDB	The World Federation of the Deafblind

Keywords

User Experience; User Interface Design; Design Heuristics; Usability; Accessibility; Usability Inspection; Accessibility Inspection, Usability Testing; Older Persons.

Disclaimer

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Executive Summary

This deliverable describes key design guidelines and recommendations that intend to inform the decisions of those involved in designing SHAPES platform and digital solutions. It also offers guidance on the evaluation of important contributors to user experience, namely user interface design, accessibility, and usability. The content of the deliverable is based on existing guidelines, patterns, standards and on an in-depth analysis of published evidence. These were complemented and informed by the outcomes of Task 2.1: Understanding Older People: Lives, Communities, and Contexts (to a limited extend as the deliverable of this task is due on month 24); Task 2.5: SHAPES Personas and Use Cases; and Task 3.5: User Requirements for the SHAPES Platform; and subject of fruitful discussion with partners. In summary, this deliverable is the result of:

- A scoping review of reviews on the usability of digital solutions directed at older adults, which included 22 systematic reviews and one narrative review.
- Literature searches on specific topics (e.g., user interface design, remote usability testing).
- Contributions from partners of work package 5 and Tasks 2,1, 2,5 and 3,5 via teleconferences and email exchanges.

This deliverable contains the following eight chapters:

1. Introduction.
2. Adopted terms and definitions.
3. User Experience.
4. User Interface Design.
5. Usability Inspection Methods.
6. Usability Assessment Involving Users.
7. User Interface Design and Usability Assessment of SHAPES platform and digital solutions.
8. Consensus Generating Procedure on User Interface Design Guidelines and Usability Assessment

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This deliverable will ensure that SHAPES platform and respective digital solutions' requirements, based on the user needs and preferences, are successfully met and that both the SHAPES platform and digital solutions will grant an intuitive, natural and rewarding user experience.

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1 Introduction

1.1 Rationale and Purpose of the Deliverable

User experience is a broad and complex concept that encompasses the user's emotions, beliefs, preferences, perceptions, comfort, behaviours, and accomplishments that occur before, during and after using a product or a service. It is influenced by personal factors, such as previous experiences, knowledge, and attitudes, as well as the context of use [1]. Accordingly, user experience is unique to each individual and for a specific moment in time.

Due to the complex and multidimensional nature of user experience [2], there is a need to operationalize this complex concept into different attributes, which can then be characterised and assessed.

This deliverable addresses two of the most important developmental processes that play a part in and modulate the user experience of SHAPES platform and digital solutions: (i) user interface design (i.e., good practices that should be considered in the development of a digital solution to optimize the quality of its user interaction); and (ii) usability assessment (i.e., evaluation of the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specific context of use [1]. Moreover, it should be noted that, for the purpose of this deliverable, accessibility (i.e., the capacity of a product or a service being accessed by persons with disabilities) is considered a precondition for usability [3], [4], which means that accessibility problems constitute a subtype of usability problems [5].

Considering that user interface design, accessibility and usability are interconnected and impact user experience, the objective of this deliverable is to provide a comprehensive framework to support the development of SHAPES platform and digital solutions, aiming to support the work developed by the partners involved in the design, development, implementation and/or evaluation of the SHAPES platform and digital solutions. For that, this deliverable includes general and specific recommendations that aim to optimize the design and usability of user interfaces and, consequently, to optimize the user experience they offer. More specifically, the deliverable includes:

- A set of recommendations on the design of user interfaces for different technological supports and different types of target users.
- A set of recommendations to guide the inspection of SHAPES platform and digital solutions, and to verify their compliance in terms of usability and accessibility.

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- A set of recommendations to guide the usability assessment of SHAPES platform and digital solutions involving users.
- A set of specific recommendations on user interface design, usability inspection and usability assessment by users, considering the specificities of the SHAPES platform and digital solutions.

To achieve these objectives, this deliverable:

- Is based on in-depth literature reviews, including a scoping review of reviews and specific literature searches to identify information about heuristics applied to interface design, and well-established good practices and international standards related to user interface design, usability, and user experience.
- Considers the results of other SHAPES work packages, namely Tasks 2.1, 2.5, and 3.5.
- Includes the comments of SHAPES partners.

1.2 Structure of the Deliverable

This document is divided into six mains chapters addressing the following main topics:

- **User Experience** – this chapter is devoted to the concept of user experience and sets the scene for the remaining chapters.
- **User Interface Design** – this chapter identifies a set of recommendations that should be considered when designing a digital solution.
- **Usability Inspection Methods** – this chapter synthetizes existing procedures for the assessment of digital solutions by usability experts.
- **Usability Assessment Involving Users** – this chapter synthetizes existing procedures for the usability assessment based on test methods involving users and proposes a framework and a set of recommendations to optimize both the assessment and the reporting.
- **User Interface Design and Usability Assessment of SHAPES Platform and Digital Solutions** – this chapter is grounded on previous chapters and summarises a set of recommendations considering the specificities of the SHAPES' platform and respective digital solutions.
- **Consensus Generating Procedures on User Interface Design Guidelines and Usability Assessment** – this chapter details the methods

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aimed to achieve consensus among SHAPES partners on a set of recommendations on user interface design, usability inspection and usability assessment by users.

1.3 Methods

The starting point of this deliverable was a scoping review of reviews on usability of digital solutions directed at older persons. The aim was to identify and describe relevant literature on the topic published between 2009 and 2020.

This study followed the five-stage scoping review methodology defined by Levac et al. [6]: (i) identification of the research question; (ii) identification of relevant studies; (iii) selection of relevant studies; (iv) charting the data; and (v) collating, summarizing, and reporting the results of the review.

The expressions "usability" OR "user experience" were used in the electronic search carried out in PubMed, ACM Digital Library, IEEE, Scopus, and Web of Science. Databases were searched for English language articles published from 2009 through the 23rd of January 2020.

Differences in judgment were used to define inclusion and exclusion criteria and were discussed until consensus was reached. To be included in this scoping review, studies had to report on user interface design or usability assessment procedures for any type of digital solution that could be relevant for older persons. In addition, studies had to: (i) be published in English; (ii) report reviews, either systematic, scoping or narrative reviews; and (iii) address and synthesize evidence on any of the steps or methods used for user interface design and usability assessment in general or for a specific digital solution that was considered of relevance to older persons or those caring for older persons, such as informal caregivers, family members or healthcare professionals.

Studies were excluded if: (i) were overall unrelated to the study topic (e.g., chemistry field); (ii) targeted children or younger age groups (e.g., digital solutions for children with diabetes); (iii) addressed non-digital solutions (e.g., buildings) or digital solutions that had no interest for older persons or those caring for them (e.g., Moodle and eLearning solutions); and (iv) addressed usability of digital solutions for older persons' caregivers but that did not involve interaction with / feedback from older persons.

A total of 3958 studies were identified. These studies were assessed against inclusion and exclusion criteria by at least two researchers and disagreements were discussed and resolved by consensus. A total of 23 reviews matched the eligibility criteria. Details of these reviews were then extracted, including aims, methods, characteristics (e.g., number of primary studies) and results.

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The results of the scoping review were used to ground chapter 4: User Interface Design (i.e., in terms of identification of design principles or heuristics related to user interface design, namely targeting specific technologies and older persons), chapter 5: Usability Inspection Methods (i.e., to identify heuristics being used to support inspection methods to assess usability and accessibility), and chapter 6: Usability Assessment Involving Users (i.e., to identify user-centred methods and procedures to assess the usability of digital solutions directed at older persons).

To complete chapter 4, the results of the scoping review were further complemented with specific literature searches using Google Scholar, Scopus and Web of Science in order to identify additional information related to heuristics used in interface design, particularly those related to older persons and supported in different technological supports (e.g., web, mobile and multimodal), in accessibility best practices, and in international standards to support the interface design and the usability of digital solutions. All the retrieved information was analysed and consolidated to propose a set of general recommendations, including recommendations to guide the user interface design, and the inspection and testing procedures to assess the accessibility and the usability of digital solutions.

A summary of recommendations based on chapters 4, 5 and 6 is provided in chapter 7: User Interface Design and Usability Assessment of SHAPES Platform and Digital Solutions. This chapter also congregates information on the tasks that inform and are informed by the deliverable and on ethics.

Finally, chapter 8: Consensus Generating Procedure on User Interface Design Guidelines and Usability Assessment, presents the methods to generate consensus among SHAPES partners and, potentially, involving partners from other European projects. This results in two sets of recommendations: one set of mandatory recommendations and a set of recommendations that although desirable, are not mandatory, as the decision to follow or not the recommendations may depend on the type of digital solution and on the characteristics of the user.

In sum, the methodological approach used in this deliverable guarantees that the user interface design and usability assessment of SHAPES platform and digital solutions are grounded on the existing evidence of good practices, but also practical, specific, and SHAPES-oriented recommendations.

1.4 Development Process of the Deliverable

The collection of information from the published literature (as detailed above) was followed by a set of contributions made by all SHAPES partners, as detailed below:

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- 12.02.2020 – teleconference with work package 5 partners to discuss and approve the deliverable's table of contents;
- 28.05.2020 – teleconference with the work package 5 leader to discuss a preliminary version of the deliverable and set a date for a preliminary version of the delivery;
- 08.06.2020 – a preliminary version of the deliverable was sent to all work package 5 partners, to the leaders of tasks 2.1, 2.5 and 3.5, and to representatives of work package 4, along with a list of structured questions to guide their comments;
- 17.06.2020 – teleconference with project manager to discuss the inclusion and details of the proposed "Consensus Generating Procedure on User Interface Design Guidelines and Usability Assessment";
- 25.06.2020 - teleconference with work package 5 partners, representatives of work package 4 and leaders of tasks 2.1, 2.5 and 3.5 to discuss the deliverable's content.

Editing, comments and questions raised by the partners were included in the deliverable resulting in the final version sent for internal revision.

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2 Adopted Terms and Definitions

The meaning of concepts that are applied in different interdisciplinary knowledge areas (e.g., healthcare, technology and design) need to be clarified in a precise and consistent manner. This chapter aims to provide an overview of the main adopted terms in this deliverable that could lead to some misunderstanding or overlapping (Table 4). The terms highlighted with an asterisk (*) and their respective definitions were retrieved from ***SHAPES Terminology V1.0*** document (15/06/2020).

Table 4 Adopted terms and definitions

Adopted terms	Definition
Accessible design	Design focused on diverse users, ensuring that as many users and contexts of usage as possible are accommodated. This aim can be achieved by designing systems that are easily usable by most users without any user interface or structure modification, and by having standardized interfaces to be compatible with assistive products and technology [7].
Activity limitations	Difficulties that an individual can experience when performing an activity [7].
Assistive product	Any system (including equipment, instruments, devices and software), especially produced or generally available for participation, protection, support, train, measure or substitution of body functions/structures and activities, or to prevent impairments, activity limitations or participation restrictions, used by or targeted at persons with disability [7], [8].
Assistive technology	A system that is used to increase, maintain, or improve capabilities of persons with disability. Assistive technology can also include assistive services, and professional services needed for assessment, recommendation, and provision. Assistive technology helps people who have difficulty, e.g., remembering, learning, seeing, hearing, pointing, speaking, typing, writing, and walking [7], [9].
Caregiver*	Includes workers providing personal care and other family member providing support to a relative, or to a

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	person who lives in the same household. The word carer can be used as a synonym. The latter term is used in Directive (EU) 2019/1158 of the European Parliament and of the Council of 20 June 2019 on work-life balance for parents and carers and repealing Council Directive 2010/18/EU PE/20/2019/REV/1 (OJ L 188, 12.7.2019, p. 79–93). This directive states that: "carer' means a worker providing personal care or support to a relative, or to a person who lives in the same household as the worker, and who is in need of significant care or support for a serious medical reason, as defined by each Member State (Article 3 lett. d of Directive (EU) 2019/1158). The word informal carer can be used to refer to a relative/family member/ or someone that has caring responsibility which are not related to his/her employment contract.
Context of use	Combination of users, goals and tasks, resources, physical and social environments, and technology conditions in which a system is used [1], [7].
De facto standards	De facto standards (also mentioned as standards in actuality) are widely adopted in the industry field. These standards are established by means when a critical mass/group of stakeholders adopt these standards in their daily work and use them collectively and over an extended period of time [10], [11]. De facto standards assume different types. For instance, they can be owned by one or more stakeholders; its access can be open or closed to everyone or only to specific users (e.g., members of a company/institution/organization). De facto standards can become de jure standards. For that, they must be approved by a formal standard organization (e.g., International Standards Organisation – ISO; Institute of Electrical and Electronic Engineers – IEEE).
De jure standards	De jure standards (also mentioned as standards according to law) are established by formal standards organizations. The responsible organization approves the standards according to the official procedures and assigns a stamp of approval so it can be applied by the stakeholders in conformance [10], [11]. On a global level, the International Standards Organisation (ISO) is

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	the organisation that determines most of the de jure standards, counting over 23.200 international standards in several areas, including Healthcare technology [12]. This particular field can benefit from standardization, since it helps to ensure technology implementation efficacy and effectiveness, and the semantic and physical interoperability between digital solutions, enabling cross-platform interaction and a meaningful data flow [13].
Design	The word design is defined in two main dimensions: (i) as a verb – the act of creating, and (ii) as a noun – the resulting concept of, or plan for, a product or system. In the present deliverable, design is used as a verb [14].
Design principles or heuristics	Broad “rules of thumb” or design guidelines that describe features of systems, guiding designers and developer’s design efforts [15], [16].
Disability	Disability is a broad term that encompasses impairments, activity limitations or participation restrictions [17].
Expert	The person that assesses the various aspects of user interaction and who is a usability specialist [18].
Generic heuristics	Sets of heuristics that guide interface designers or evaluators and that are independent of the type of digital solutions being developed [18].
Guideline	Information aiming to advise people on how something should be done or relating to what something should be [19].

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Healthcare/care services provider or **care services***	Provider of long-term/short-term healthcare services , regardless its national legal status or the economic nature of its activity. This broad definition is stated in Directive 2011/24/EU of the European Parliament and of the Council of 9 March 2011 on the application of patients' rights in cross-border healthcare OJ L 88, 4.4.2011, p. 45–65). According to this Directive "'healthcare provider' means any natural or legal person or any other entity legally providing healthcare on the territory of a Member State" (Article 3 lett. g). The word "care providers" is more general to encompass healthcare and other social services. In the EPRS the word "care services" is used "Everyone has the right to affordable long-term care services of good quality, in particular home-care and community-based services" (principle 18). We acknowledge however that: • The Medical Device Regulation (Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices, amending Directive 2001/83/EC, Regulation (EC) No 178/2002 and Regulation (EC) No 1223/2009 and repealing Council Directives 90/385/EEC and 93/42/EEC OJ L 117, 5.5.2017, p. 1–175) uses the wording 'health institution' to refer to "an organisation the primary purpose of which is the care or treatment of patients or the promotion of public health" (Article 2 para 36) • Health care systems differ significantly between Member States. In EU law, the fact that a health service is provided by a public entity is not sufficient for the activity to be classified as non-economic (Communication from the Commission on the application of the European Union State aid rules to compensation granted for the provision of services of general economic interest - Text with EEA relevance - OJ C 8, 11.1.2012, p. 4–14)

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Impairments	Problems in body function or structure, or mental functioning (e.g., activity limitation such as difficulty walking; memory loss) [7], [20], [21].
Informed consent*	The Medical Device Regulations defines informed consent as a subject's free and voluntary expression of his or her willingness to participate in a particular clinical investigation, after having been informed of all aspects of the clinical investigation that are relevant to the subject's decision to participate or, in the case of minors and of incapacitated subjects, an authorisation or agreement from their legally designated representative to include them in the clinical investigation.
Older persons*	We suggest the use of “older people/persons”. This term is the one that is used in most United Nation documents and is consistent with a rights-based approach to age. Occasionally, the term “elderly persons” can be used. This term, however, is to be understood in light of the rights-based approach to ageing which this project endorses. The European Pillar of Social Rights refers to “everyone in old age”. The latter expression “old age” can be used occasionally when referring to the EPSR. We suggest avoiding terms that might appear discriminatory and can show prejudicial attitudes and stereotypes.
Persons with disabilities*	This is the term adopted by the Convention on the Rights of Persons with Disabilities (CRPD) and it is referred to as ‘people-first language’. The CRPD 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. This definition is also adopted in EU law (see EAA, interpretation of Directive 2000/78 by the CJEU, GBER). Discriminatory and stigmatizing terms must be avoided (e.g., handicapped, disabled, invalid, unable, incapable, mentally handicapped, mentally sick, backward, retarded, mentally or physically impaired, slow demented). Full legal incapacitation (while it is still

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	possible in many countries) is not in compliance with the CRPD.
Pilot (theme) leader*	The leading pilot site of SHAPES' seven pilot themes (1-CCS, 2-GEWI, 3-NHSCT, 4-UAVR, 5-UPORTO, 6-SAL/UCLM, 7-5thYPE).
Pilot sites / Replicating sites*	Pilot sites are local areas in which the pilot activities in WP6 will take place. SHAPES includes 15 pilot sites: Responsible for these pilot sites are AIAS, AUTH, CCS, CH, 5thYPE, FNOL, GEWI, NHSCT, OMN, SAL, UP, UAVR, UCC, UNRF, UPORTO. The replicating sites are pilot sites which replicate a specific use case (after the use case leader).
Satisfaction	Freedom from discomfort, and positive attitudes towards the use of a system [7].
SHAPES digital solutions*	Set of technologies, systems and mobile applications that are part of the SHAPES platform, including assistive robots, eHealth sensors and wearables, Internet of Things (IoT)-enabled devices and mobile applications (Apps).
SHAPES recommendations*	Set of guidelines, roadmap and action plan, including a set of priorities dedicated to standardisation, to support key EU stakeholders to foster the large-scale deployment and adoption of digital solutions and new integrated care services in Europe.
SHAPES technological platform*	Technological framework developed in the SHAPES project that combines devices, software and accessible modes of interacting, therefore driving the interconnection and integration of the SHAPES Digital Solutions.
Specific heuristics	Specific heuristics applied to a particular class of products or types of users, as a complement to the generic heuristics [23].
System	Product, service or built environment, or any combination of them, with which the user interacts with [7].
Universal design	Design of systems to be usable by all people to the greatest extent possible without the need for

	adaptation or specialized design. Terms such as universal design, accessible design, design for all, barrier-free design, inclusive design, and transgenerational design are often used interchangeably with the same meaning [7], [24].
Usability	The extent to which a system can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use [7].
Use case leader*	The pilot site which leads the development of a specific use case and starts the planning and implementation of the pilot activities regarding this specific use case. In most cases, the pilot (theme) leader is also the use case leader.
User	Person who accesses or interacts with a system [1], [7].
User accessibility need	User need related to features that are necessary for a system to be accessible [7].
User experience	User's perceptions and responses that result from the use and/or anticipated use of a system. Users' perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviours, and accomplishments that occur before, during and after use, and result from prior experiences, attitudes, skills, abilities, and personality; and from the context of use [1].
User interface	User-visible components of an interactive system (software or hardware) that provide information and controls for the user to accomplish specific tasks with that system [1].
User interface design	The design of user interfaces for software and hardware, focused on ensuring a good usability and user experience [25], [26].

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3 User Experience

This chapter defines and distinguishes between user experience and usability, terms often used as synonymous, and presents the attributes that influence user experience. It also presents the user experience design process, stressing that the SHAPES solutions' design will only accomplish its goals if the process is focused on users and on their engagement in the process of developing SHAPES platform and its digital solutions from the very beginning.

3.1 Usability, Accessibility and User Experience

Usability has been a topic of interest since the mid-1980s, establishing its route in several international conferences, and achieving its strength in the 1990s through the widespread use of personal computers [14], [16], [27]–[30]. Usability also emerged to replace the term user-friendly, which by the early 1980s had acquired a "host of undesirably vague and subjective connotations" [30, p. 1].

In the early 1990s, Bevan et al. [30, p. 4] introduced the following usability definition, underlining at the time some qualities of usability: "Usability lies in the interaction of the user with the product or system and can only be accurately measured by assessing user performance, satisfaction, and acceptability. Any change in the characteristics of the product or system, user, task, or environment may produce a change in usability. A product is not itself usable or unusable but has attributes which will determine the usability for a particular user, task, and environment". Later, in 2001, usability was recognized as a criterion for software quality by the standard ISO 9126-1 [31, p. 9]: "The capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions".

Still in the last century, in the scope of research related to usability, different design principles or heuristics were proposed for the user interface design (e.g., the *10 Usability Heuristics for Interface Design* [15]) and various usability evaluation methods were elaborated (e.g., heuristic evaluation [16]).

In parallel, the desire of making all kinds of digital solutions usable by all possible categories of users promoted the importance of accessibility, which is a prerequisite for basic use of products by older persons and persons with disabilities [3], [4]. In the literature, the definition of accessibility has a tight connection with usability [33]. For instance, the ISO 9241-171 [34] and ISO 9241-20 [35] define accessibility as ''usability of a product, service, environment or facility by people with the widest range of capabilities''. In turn, Thatcher et al. [5] claimed that accessibility is a subset of usability, signifying that accessibility

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problems constitute a sub-type of usability problems that might hinder access for people with disabilities.

The usability concept was continuously rebuilt to surpass some criticisms that derived from its ambivalence and from how it should be oriented: (i) product-oriented – usability can be measured in terms of a solution's ergonomic attributes; (ii) user-oriented – usability can be measured in terms of the users' mental effort and attitudes towards the solution; or (iii) user performance – usability can be measured by examining how users interact with a solution, namely regarding how easy it is to use and what is the solution' prospect of being used once it is deployed [31], [36]–[38].

As a consequence, the usability-focus was abandoned and a user experience approach proposed [26], aiming to embrace the total usage phenomenon and including the emotional impact that a product or service can have in the users' lives [14]. Since then, the term user experience has become widely used. However, as a result of many years of human-computer interaction practices meeting engineering aspects, user experience has been treated as being the same as user interface and used within a usability-focused approach. Despite user interface and usability being of paramount importance to good user experience, it is not the whole of the experience. User experience is also concerned and deeply entailed with a social and cultural design of solutions, and with the emotional aspects behind the solution usage (e.g., pleasant use and meaningfulness to users' daily life) (Ibid.).

Although widely used, the term user experience has, in the past years, been understood and used in many different ways, the reason why a group of 30 experts worked on a user experience white paper, gathering some clarification on the term [38, p. 4]: User experience "is not the same as usability, although usability, as perceived by the user, is typically an aspect contributing to the overall" user experience.

ISO 9241-210:2019 is aligned with this clarification, defining user experience as the "user's perceptions and responses that result from the use and/or anticipated use of a system, product or service", clarifying that users' "perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviours, and accomplishments that occur before, during and after use"; and that it also results from "prior experiences, attitudes, skills, abilities, and personality; and from the context of use" [1]. Thus, user experience is grounded mainly on intangible aspects, the reason why we cannot design a user experience since it can only be experienced [2]. This means that different users and different usages of the same system, product, or service can result in different user experiences and different usability experiences.

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User experience design is, then, concerned on providing an enjoyable and positive usage, not only before (when thinking, e.g., about the solution requirements and graphical design targeting the end-users), but also during and after the interaction with the system, product or service [2], [14]. A good user experience will therefore require, as much as possible, a total focus on the mental models of the target users, so that the conceptual model of the solutions matches their expectations and, with that, we can assure a positive and useful experience [40].

3.2 Attributes that Influence the User Experience

One proposed model for user experience considers that there are seven main attributes that influence user experience; these are being useful, usable, findable, credible, desirable, accessible, and valuable [41], [42].

Usefulness is the starting point of the user experience [43]. If a solution is not useful and if it does not meet the user's needs, then the user experience ceases in that precise moment, since the solution does not make sense to the user. This means that usefulness is the utility of a system, product, or service to a particular user or group of users [15]. It is the attribute of user experience related to the ability of the solution to accomplish its goals (e.g., sharing a photo on Instagram®) [14], [44]. Usefulness is also highly linked to usability aspects. Although usefulness is mostly related to the conscious user needs, usability and aesthetic aspects can stimulate user's subtle and even subconscious needs, informing about the indirect usefulness of a solution.

Usability is the most pragmatic attribute of user experience [15]. It refers to the extent to which a solution can be used in a specific context by specific users to achieve specific goals with effectiveness, efficiency, and satisfaction, assuring that (i) the user interface is easy to use; (ii) users can perform a task without inconvenience or delay and in a reasonable number of steps; (iii) the information is easy to understand; and (iv) the user is not cognitively exhausted from the user experience [1], [45]. Since the usability attribute is grounded on measurable qualities, it is commonly tested both by experts and users to assure the adequacy of the solution. The most common evaluated aspects regard to the learnability/ease of use (e.g., Is it simple to use? Is it flexible? Can I use it without instructions?), and satisfaction qualities (e.g., Would I recommend it to a friend? Does it work the way I want it to? Do I feel I need to use it?) [14], [15], [42].

Findability is the user experience attribute related to how easy it is to find information within an interface solution, i.e., the quality of an object or information being easily locatable or navigable [42]. From an e-commerce perspective, it also refers to the idea that a solution must be easy to find (e.g., online search process using keywords to find products, services, news) [46]. This attribute is highly

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correlated to usability and it can reflect, in the very first minutes of a solution usage, a good or bad user experience, once it conveys to the users a sense of power and freedom in its use [47]. Regardless of the type of solution (e.g., a smartphone interface, a website, online store), findability is a crucial attribute. If users cannot find what they are looking for in a solution, they will simply abandon it. To assure good findability, the design must provide a user experience as tailored as possible to the user's needs and intentions [48].

Credibility is the user experience attribute that determines whether a solution will be used for an amount of time or not [49]. It relates to the users' trust in the solution (and information) provided. Considering the number of solutions currently available, users are increasingly concerned with finding and using the most credible ones [50]. Credibility's importance has been established under a variety of quantitative studies conducted at the Stanford's Persuasive Technology Lab (Ibid.). Morville [47] underlines that the credibility of a solution becomes even more important in the health information field as most of the people use digital solutions in this field to validate doctor's diagnosis or advice, look for a "second opinion", and/or to deepen their knowledge or feel better informed and more confident.

Desirability is related to the emotional impact of a solution on the users, which is reflected in the third major element of the ISO usability definition: satisfaction [36]. Desirability is the emotional attribute of user experience, prompting the users' feelings that include aspects such as aesthetics, pleasure, fun, joy of use, novelty, and originality, "and can involve deeper emotional factors such as self-expression, self-identity, a feeling of contribution to the world, and pride of ownership" [43, p. 6]. This attribute is the least tangible, however, it is probably the one that in the first contact with the solution determines if the users will use it or not [36]. Furthermore, the more desirable a solution is, the more likely it is that users will share their good experiences and influence other people to use it.

Accessibility is the cross-attribute of user experience. Unfortunately, it is often forgotten in the user experience design process [51]. The term accessibility is commonly linked to disabilities; nevertheless, designing an accessible solution means providing a good user experience to a wide range of people and in as many contexts as possible [52]. This includes people without and with disabilities (e.g., hearing loss, impaired vision, motion impaired or learning impaired), and the usage of any kind of devices (e.g., computers, mobile devices, television, watches) and assistive technology (e.g., screen readers, special keyboards, pointing devices, eye-gaze and head trackers). The guide for addressing accessibility in standards [7] underlines that accessible design should be focused on diverse users and contexts of use, increasing the solution usage without any specific modification, by providing adaptable and compatible user interfaces with assistive technology. Since accessible design is now a legal obligation in many jurisdictions, including the European Union, designing a solution from scratch that meets the requirements for accessibility will allow fewer future adaptations and that more users benefit from it [53]. Accessibility represents an opportunity to make a solution "usable to all people regardless of their abilities, economic situation, age, education, or geographic location" [54].

The last attribute of user experience is being valuable to the solution providers and sponsors and the users of the system, product, or service provided [42]. For companies, the value will arise from meeting the initial goals and improve users' involvement and satisfaction with the solution. For non-profits, user experience must advance the organization's mission (e.g., gain more followers and curators). Finally, for users, a valuable user experience will derive from the enrichment the solution will bring to their lives (e.g., mobile app for older persons that reads and tracks their blood pressure and weight, helping them to oversee their health regimen and stay in shape without having to regularly consult a doctor). This attribute is right in the centre of the user experience [41] as it depends on the other six attributes presented above. In other words, a solution will only be valuable to the users if it is useful, usable, findable, credible, desirable, and accessible.

3.3 The Design Process

As detailed in the previous section, user experience encompasses several attributes that relate to how the users think about a solution (useful, valuable and credible); how the users feel about it (credible and desirable); and how the users use it (usable, findable and accessible). Considering its complexity, Hartson and Pyla [14, p. 7] clarify that "you can't design something that occurs internally in a user". So, whilst the intention to design user experience makes no sense, the interface design (i.e., the physical space where interactions between the users and a digital solution occur) and the usability (i.e., the quality of user interface, covering whether digital solution is easy to learn, effective, efficient to use and pleasant to specified users in a specified context of use) definitely impacts user experience.

That is, by assuring a good user interface design, digital solutions will be striving for a good usability and, thereby, enhancing a good user experience [1], [14], [27], [46], [51], [55]–[57]. Moreover, the impact of the digital solution on the life of users, which in SHAPES will be assessed in different pilots, is also an important contribution to the user experience.

The design process results from the design team's decisions, which in turn should be focused on the users. This means that users should be engaged from the beginning to the end of the design process. Although different models can be identified, in general, a design process follows different stages. For instance,

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Doorley et al. [58] and Komninos [59] have set five stages: (i) Empathize with users; (ii) Define the problem; (iii) Ideate; (iv) Prototype; and (v) Test. The first three stages aim to understand, state and explore possible answers to the design problem. In turn, the prototype stage aims to experiment the ideated solution, identify the best choices for each of the parts of the solution, and highlight the issues identified during the first three stages [58]–[60]. Finally, the test stage intends to get users, experts and stakeholders' feedback, to refine the solution, and to continue to learn about users (Ibid.).

For the design process, there is a consolidated knowledge in terms of heuristics (e.g., how to design windows, icons, buttons, menus, forms) that is fundamental to consider when designing the user interface of a digital solution. This consolidated knowledge is presented in the chapter 4: User Interface Design.

Considering the last two stages, it is necessary to employ robust methods to determine the usability of the user interface that is related to the quality of the user interface design. Indeed, usability problems can prevent the correct use of digital solutions, which is even more important in health and wellbeing-related solutions. Particularly in the health and social domains, usability problems might represent serious safety concerns and, ultimately, accidents, injuries, and even death [14].

However, when analysing usability studies it becomes evident that a significant number of studies present low quality both in terms of planning the experimental design and reporting the results [61]. Therefore, chapters 5 and 6 of this deliverable are focused on recommendations for usability assessment. Chapter 5: Usability Inspection Methods addresses the inspection methods to be used by usability experts, and chapter 6: Usability Assessment Involving Users addresses test methods to be used for usability assessment by users. The recommendations outlined in chapters 4, 5 and 6 establish a comprehensive framework that, in chapter 7: User Interface Design and Usability Assessment of SHAPES Platform and Digital Solutions, is instantiated to the specific needs of the SHAPES platform and the respective digital solutions.

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4 User Interface Design

This chapter addresses user interface design principles or heuristics to promote a coherent, intuitive, natural, and rewarding user interaction. A set of general heuristics were consolidated based on widely recognized, accepted, and applied heuristics proposed by different authors.

These general heuristics were further complemented by a review of relevant literature and the identification of existing user interaction and accessibility standards aiming to ground an analysis of existing good practices to guide user interface design of digital solutions targeting older persons in specific application domains (e.g., health and social applications) or based on specific technological support (e.g., web, mobile and multimodal). The identified good practices were consolidated as a set of specific recommendations for the development of the SHAPES platform and digital solutions.

Chapter 4 aims to support the work developed by the partners involved in the design and development of the SHAPES platform and digital solutions.

4.1 Generic Sets of Heuristics to Support User Interface Design

In 1993, Jakob Nielsen proposed the *10 Usability Heuristics for User interface Design* [15], in 1996, Jill Gerhardt-Powals presented the *10 Cognitive Engineering Principles* [62], and, in 1998, Ben Shneiderman proposed the *8 Golden Principles of Good Interface Design* [63]. These three sets of heuristics have been widely used as high-level guidance to help designers decision-making processes during the user interface design process. Table 5 shows the existing commonalities amongst the three sets of heuristics ([64].

Table 5 User interface design heuristics

Principles	**Nielsen** [15]	**Shneiderman** [63]	**Gerhardt-Powals** [62]
System status visibility	x		
Simple and daily life terms	x		x
Exit, undo, and redo options	x	x	
Content consistency	x	x	x

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Error avoidance	x		
Object and option visibility	x		
Flexibility	x	x	
Information relevancy	x		
Error message simplicity	x	x	
Feedback and guidance	x	x	
Logical presentation		x	x
Simplicity of layout		x	
Avoidance of memory load			x
Information clustering			x
Graphics instead of text			x

To have a clear picture on the heuristics and give practical recommendations on how to design an interface, meeting the pre-defined heuristics, a definition for each one is provided. For that, original references were analysed and assigned to each heuristic in the original meaning. Since most of the heuristics combine different sources, it was decided to present this information in Table 6.

Table 6 Ahmad et al. [64] Heuristics and Used Sources

System status visibility	Nielsen [15]: Visibility of system status – The system should always keep users informed about what is going on, through appropriate feedback within a reasonable time.
Simple and daily life terms	Nielsen [15]: Match between system and the real world – The system should speak the users' language, with words, phrases, and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

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	Gerhardt-Powals [61, p. 192]: Present new information with meaningful aids to interpretation – New information should be presented within familiar frameworks (e.g., schemas, metaphors, everyday terms) so that information is easier to absorb.
Exit, undo, and redo options	Nielsen [15]: User control and freedom – Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo. Shneiderman [63]: Permit easy reversal of actions – This feature relieves anxiety, since the user knows that errors can be undone; it thus encourages exploration of unfamiliar options. The units of reversibility may be a single action, a data entry, or a complete group of actions; such as entry of a name and address block
Content consistency	Nielsen [15]: Consistency and standards – Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions. Shneiderman [63]: Strive for consistency – Consistent sequences of actions should be required in similar situations; identical terminology should be used in prompts, menus, and help screens; and consistent commands should be employed throughout. Gerhardt-Powals [61, p. 193]: Group data in consistently, meaningful ways – Within a screen, data should be logically grouped; across screens, it should be consistently grouped. This will decrease information search time.
Error avoidance	Nielsen [15]: Error prevention – Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

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Object and option visibility	Nielsen [15]: Recognition rather than recall – Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
Flexibility	Nielsen [15]: Flexibility and efficiency of use – Accelerators – unseen by the novice user — may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions. Shneiderman [63]: Cater universal usability – Recognize the needs of diverse users and design for plasticity, facilitating transformation of content. Novice-expert differences, age ranges, disabilities, and technology diversity each enrich the spectrum of requirements that guides design. Adding features for novices, such as explanations, and features for experts, such as shortcuts and faster pacing, can enrich the interface design and improve perceived system quality. Shneiderman [63]: Enable frequent users to use shortcuts – As the frequency of use increases, so do the user's desires to reduce the number of interactions and to increase the pace of interaction. Abbreviations, function keys, hidden commands, and macro facilities are very helpful to an expert user.
Information relevancy	Nielsen [15]: Aesthetic and minimalist design – Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
Error message simplicity	Nielsen [15]: Help users recognize, diagnose, and recover from errors – Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution. Shneiderman [63]: Prevent errors – As much as possible, design the system such that users cannot make serious errors; for example, layout menu items that are not

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	appropriate and do not allow alphabetic characters in numeric entry fields (…) If a user makes an error, the interface should detect the error and offer simple, constructive, and specific instructions for recovery. (…) Erroneous actions should leave the system state unchanged, or the interface should give instructions about restoring the state. Shneiderman [63]: Offer simple error handling – As much as possible, design the system so the user cannot make a serious error. If an error is made, the system should be able to detect the error and offer simple, comprehensible mechanisms for handling the error.
Feedback and guidance	Nielsen [15]: Help and documentation – Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large. Shneiderman [63]: Offer informative feedback – For every operator action, there should be some system feedback. For frequent and minor actions, the response can be modest, while for infrequent and major actions, the response should be more substantial.
Logical presentation	Shneiderman [63]: Design dialogue to yield closure – Sequences of actions should be organized into groups with a beginning, middle, and end. The informative feedback at the completion of a group of actions gives the operators the satisfaction of accomplishment, a sense of relief, the signal to drop contingency plans and options from their minds, and an indication that the way is clear to prepare for the next group of actions. Gerhardt-Powals (1996, p. 192): Present new information with meaningful aids to interpretation – New information should be presented within familiar frameworks (e.g., schemas, metaphors, everyday terms) so that information is easier to absorb.
Simplicity of layout	Shneiderman [63]: Reduce short-term memory load. The limitation of human information processing in short-term memory (the rule of thumb is that humans can remember

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	"seven plus or minus two chunks" of information) requires that displays be kept simple.
Avoidance of memory load	Gerhardt-Powals [61, p. 192]: Automate unwanted workload – Eliminate mental calculations, estimations, comparisons, and any unnecessary thinking, to free cognitive resources for high-level tasks.
Information clustering	Gerhardt-Powals [61, p. 192]: Fuse data – Bring together lower level data into a higher-level summation to reduce cognitive load.
Graphics instead of text	Gerhardt-Powals [61, p. 193]: Limit data-driven tasks – Use colour and graphics, for example, to reduce the time spent assimilating raw data.

Analysing the definition of the 15 heuristics in Table 6 revealed some concept overlapping. Accordingly, some of the principles can be assembled, namely:

- **Logical presentation**: according to Gerhardt-Powals [61, p. 192] “new information should be presented within familiar frameworks (e.g., schemas, metaphors, everyday terms) so that information is easier to absorb”. This principle can be included in the Simple and daily life terms principles.
- **Avoidance of memory load**: according to Gerhardt-Powals [61, p. 192] design should “Eliminate mental calculations, estimations, comparisons, and any unnecessary thinking, to free cognitive resources for high-level tasks”. This principle (Avoidance of memory load) is already foreseen in the Object and option visibility principle.
- **Information clustering**: according to Gerhardt-Powals [61, p. 192] design should “Bring together lower-level data into a higher level summation to reduce cognitive load”. This principle is already foreseen in the Content consistency principle.
- **Graphics instead of text**: according to Gerhardt-Powals [61, p. 193] design should “Use colour and graphics, for example, to reduce the time spent assimilating raw data”. This principle is already foreseen in the Object and option visibility principle. However, from an accessibility point of view, alternative text that can be accessed by any person using a screen reader, should also be provided.

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According to the exposed, Nielsen 10 heuristics [15] emerge as the most appropriate Generic Sets of Heuristics to support User Interface Design and, thus, are proposed to be used in SHAPES:

#1 **Visibility (information) of system status** – The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

#2 **Match between system and the real world** – The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

#3 **User control and freedom** – Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

#4 **Consistency and standards** – Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

#5 **Error prevention** – Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

#6 **Recognition rather than recall** – Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions to use the system should be visible or easily retrievable whenever appropriate.

#7 **Flexibility and efficiency of use** – Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

#8 **Aesthetic and minimalist design** – Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

#9 **Help users recognize, diagnose, and recover from errors** – Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

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#10 **Help and documentation** – Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

4.2 Specific Sets of Guidelines of User Interface Design

Besides the above-mentioned generic set of heuristics, there are specific heuristics that must be considered when observing SHAPES' platform and digital solutions, namely addressing accessibility issues, specific technologies, and SHAPES primary users' (older persons) characteristics/needs.

This section aims to present specific heuristics relevant for SHAPES. It is organised in three components: specific heuristics steered by the accessibility domain (4.2.1); specific heuristics driven from specific technologies (4.2.2), and specific heuristics determined by older persons' specificities (4.2.3).

This approach, based on a complementary and crossed analysis with the generic heuristics presented in the previous section, enables the development of an enriched view of the use of heuristics in the context of SHAPES and allows the proposal of a comprehensive list of heuristics as a first step for discussion, as presented in chapter 7 – User Interface Design and Usability Assessment of SHAPES Platform and Digital Solutions.

4.2.1 Accessibility Driven Heuristics

Accessibility is a very important concept in the context of this project. It can be understood as a usability prerequisite in the sense that it relates to the context of use, as well as to the users' characteristics and needs; an application that is not accessible cannot be used.

Different names have been historically used to name this concept, as Universal Design, Inclusive Design, Accessible design, or Design for all [65], [66]. Generically, accessibility efforts aim at fighting exclusion, eliminating existent barriers, and preventing new ones to ensure all users (including persons with disabilities) can equally perceive, understand, navigate, and interact with websites [67].

Accessibility and usability are closely related concepts [67]. This complementary view on accessibility and usability (valuing the specificities of users, tasks, and contexts of use) addresses interesting concerns within the scope of Universal Design and provides formal support to many of the studies and issues in the area of Accessibility. Both Shneiderman [68] and Meiselwitz et al. [69] even use the term "Universal Usability" to designate this area of study. Back in 2000,

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Stephanidis [70] argued that this new approach to usability would bring a paradigmatic shift to the Human Computer Interaction (HCI) study area, creating new challenges for the design and conception of systems aimed at a broad and heterogeneous population, characterized by a spectrum of users with different skills, preferences and needs and who use different technologies and in different contexts of use (Ibid.). Like a ramp on a sidewalk benefit not only an individual in a wheelchair but also the use of baby strollers, supermarket strollers, cyclists or wheeled suitcases, a specific adaptation in a digital application can also benefit different users [68].

When considering accessibility using this Universal Design approach, the persona spectrum gains a more complex and comprehensive dimension not limited to the scope of disability but also takes into consideration temporary impairments, such as a broken wrist, which can prove to be conditions of relative incapacity and temporary to use any application effectively, efficiently and satisfactorily. Older persons are a paradigmatic example of such cases. On the other hand, the current scenario of ubiquitous, pervasive, and emergent technologies, and new interaction paradigms amplifies this view.

Digital technologies must be accessible to all, promoting its universal use, widening the concept of user, to respond to an increasingly heterogeneous audience, including older persons. Many of the existing accessibility principles and guidelines are not limited to the specific needs of users with disabilities, increasing the levels of flexibility for all users who, depending on particular circumstances or contexts of use, may also benefit from these adaptations.

Designing according to this universal and inclusive approach can also foster principles of equity and non-segregation, and contribute to creating an enlarged view on the concept of user with special needs: “The scope of user interfaces for all is broad and complex because it involves issues on context-oriented design, diverse user requirements, as well as adaptable and adaptive interactive behaviours” [69, p. 14].

Besides understanding the user needs and the context of use, the Universal Access approach also involves including users in the design process, using participatory and co-design strategies [65], [71].

Gregg Vanderheiden was one of the first authors to systematize the principles of Universal Design, which have influenced many of the guidelines and checklists that were later published with respect to accessibility assessment [72]. Seven principles and different guidelines were proposed, as described in Table 7:

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Table 7 Principles of Universal Design [72]

Principles	Guidelines
Principle 1: Equitable use The design is useful and marketable to people with diverse abilities.	1a. Provide the same means of use for all users: identical whenever possible; equivalent when not. 1b. Avoid segregating or stigmatizing any users. 1c. Provisions for privacy, security, and safety should be equally available to all users. 1d. Make the design appealing to all users.
Principle 2: Flexibility in use The design accommodates a wide range of individual preferences and abilities.	2a. Provide choice in methods of use. 2b. Accommodate right- or left-handed access and use. 2c. Facilitate the user's accuracy and precision. 2d. Provide adaptability to the user's pace.
Principle 3: Simple and intuitive use Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.	3a. Eliminate unnecessary complexity. 3b. Be consistent with user expectations and intuition. 3c. Accommodate a wide range of literacy and language skills. 3d. Arrange information consistent with its importance. 3e. Provide effective prompting and feedback during and after task completion.
Principle 4: Perceptible information The design communicates necessary information effectively to the user, regardless of ambient	4a. Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information.

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conditions or the user's sensory abilities.	4b. Provide adequate contrast between essential information and its surroundings. 4c. Maximize "legibility" of essential information. 4d. Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions). 4e. Provide compatibility with a variety of techniques or devices used by people with disabilities
Principle 5: Tolerance for error The design minimizes hazards and the adverse consequences of accidental or unintended actions.	5a. Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded. 5b. Provide warnings of hazards and errors. 5c. Provide fail safe features. 5d. Discourage unconscious action in tasks that require vigilance.
Principle 6: Low physical effort The design can be used efficiently and comfortably and with a minimum of fatigue.	6a. Allow user to maintain a neutral body position. 6b. Use reasonable operating forces. 6c. Minimize repetitive actions. 6d. Minimize sustained physical effort.
Principle 7: Size and space for approach and use Appropriate size and space are provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.	7a. Provide a clear line of sight to important elements for any seated or standing user. 7b. Make reach to all components comfortable for any seated or standing user.

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	7c. Accommodate variations in hand and grip size. 7d. Provide adequate space for the use of assistive devices or personal assistance.

Inspired by Vanderheiden and also by research conducted at research centres such as Xerox PARC Center [65], the W3C Web Accessibility Initiative (WAI) developed important standards and support materials to implement accessibility. The Web Content Accessibility Guidelines (in its current 2.1 version) are the most important reference [73]. WCAG 2.1 includes all the eligibility criteria for the former version (2.0), adding 17 additional criteria on mobile accessibility, people with low vision, and people with cognitive and learning disabilities, amongst others[1].

These guidelines are organized in four core principles (perceivable, operable, understandable, and robust) presented in Table 8.

Table 8 Web Content Accessibility Guidelines (WCAG) 2.1 [73]

Principles	Guidelines
Principle 1: Perceivable information and user interface	Text alternatives for non-text content. Captions and other alternatives for multimedia. Content can be presented in different ways. Content is easier to see and hear.
Principle 2: Operable user interface and navigation	Functionality is available from a keyboard. Users have enough time to read and use the content. Content does not cause seizures and physical reactions.

[1] Besides WCAG, W3C also developed guidelines for (i) browsers, browser extensions, media players and some assistive technologies - User Agent Accessibility Guidelines/UAAG [254]; and also for (ii) HTML editors, content management systems (CMS), courseware tools, or content aggregators - Authoring Tool Accessibility Guidelines/ATAG [127].

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	Users can easily navigate, find content, and determine where they are. Users can use different input modalities beyond keyboard.
Principle 3: Understandable information and user interface	Text is readable and understandable. Content appears and operates in predictable ways. Users are helped to avoid and correct mistakes.
Principle 4: Robust content and reliable interpretation	Content is compatible with current and future user tools.

Some overlapping can, however, be seen between the 10 Generic Heuristics presented in section 4.1 and the Vanderheiden and WCAG 2.1 Principles. As argued by Keates [65], Universal Access innovations are also influenced by the generic principals stated previously by the works of Norman and Shneiderman. Indeed, most of the generic heuristics described in section 4.1 can be found in the underlying principles of the WCAG 2.1 Guidelines. Nevertheless, some specific heuristics emerge:

- **Equitable use** (Vanderheiden Principle 1) – The design is useful and marketable to people with diverse abilities;
- **Perceivable information** (Vanderheiden Principle 4 & WCAG Principle 1) – Information and user interface components must be presentable to users in ways they can perceive;
- **Operable user interface and navigation** (WCAG Principle 2) – User interface components and navigation must be operable.
- **Low physical effort** (Vanderheiden Principle 6) – The design can be used efficiently and comfortably and with a minimum of fatigue;
- **Size and space for approach and use** (Vanderheiden Principle 7) – Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

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4.2.2 Specific Heuristics for Specific Technologies

As the generic usability heuristics proposed by Nielsen [15] were not developed with the focus of encompassing specific technologies [74], it became necessary to identify and propose a new set of heuristics that focused on applications developed under the SHAPES context. Indeed, there are novel computer access systems and new interaction paradigms (as robotic universal access assistants) that must be considered when discussing specific heuristics [65].

In this regard, the following sections depict the list of heuristics according to the focused technologies.

4.2.2.1 Web Supports

The set of heuristics proposed by Nielsen [15] is widely used in the web supports context. Still, other works have been done to complement this heuristic evaluation framework, like the one proposed by Xerox [75]. In this work, besides Nielsen [15], a new set of 3 heuristics was considered: Skills, Pleasurable and Respectful Interaction with the User and, Privacy. Also, Baños Díaz & Zapata Del Río [76] in their work-related with E-Banking Websites added to Nielsen's [15] set the Privacy heuristic. Considering these works and the Systematic Literature Reviews from Hermawati & Lawson [77] and Fernandez et al. [78], the following heuristics are proposed in what concerns SHAPES web applications (along with the generic set previously described):

- **Pleasurable and respectful interaction with the user** – The system should provide a nice iteration with the user so that the user does not feel uncomfortable while using it;
- **Privacy** – The system should assure the protection of the user's personal and private information;
- **Security** – The security of information is the "Preservation of confidentiality, integrity, and availability of the information".

4.2.2.2 Mobile Supports

Concerning mobile supports, it should be stated that, currently, they are mostly based on web application technologies. Thus, their development and evaluation should observe the 10 Nielsen [15] heuristics' and the ones identified in the previous section. Considering the Systematic Literature Review carried out by Costa et al. [74] a subset of heuristics should be added to this list to better accommodate the specificities of the mobile environment. So, in addition to the ones already listed, SHAPES mobile supports should also consider:

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- **Customization and shortcuts** – The application should provide the user with the possibility of setting and customizing shortcuts for frequent actions [74];

- **The efficiency of use and performance** – The device must be able to load and display information in a reasonable amount of time and minimize the steps required to perform a task (number of steps to be taken by the user to reach a goal). Animations and transitions should display smoothly[74].

4.2.2.3 Multimodal Supports

Alongside web and mobile supports, specific SHAPES solutions rely on multimodal interfaces like gestures, voice, computer vision and haptic, as is the case of robotics supports. For these, there are specific interface details that are not covered by the Nielsen [15] heuristics, nor by the lists of the previous sections. The following set of heuristics was based on several Systematic Literature Reviews in this specific subject. Findings show that specific issues cannot be detected by general-purpose heuristics as they do not consider the prolonged use of a product. Besides the list of heuristics that SHAPES Multimodal supports should consider, the paragraphs below provide insights on the heuristics' application:

- **Ergonomics** – This heuristic is related to applications' comfort of use. In this regard, aspects related to fatigue are noticeable important when considering interfaces that imply user physical effort. According to Chuan et al. [79], the ergonomics heuristic did complement the general-purpose heuristics to find more issues. This heuristic could also be considered for designing products that use hand and body movement as input in a large screen environment;

- **Motivation** – In the scope of this heuristic, aspects like stimulating interest, personal innovativeness, and effort expectancy should be addressed [80];

- **Engagement** – This heuristic encompasses several perspectives concerning user emotions when using a technical solution. Aspects like attention are addressed in this heuristic [80];

- **Behaviour** – Technology usage promotes several behaviours that are part of usability metrics. This heuristic embraces aspects like the attitude towards usage and the sense of dominance [80];

- **Emotion** – Several emotions arise when using technology, which enables the characterization of its usability level. The arousal is one of these emotions and should be considered under "Emotion" heuristic [80];

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- **Fun/Amusement** – The amusement and fun felt when using, for example, augmented reality solutions, have the potential to catalyze the usability level of a solution. Aspects like fun sensation, satisfaction, and gratification levels should also be considered under this heuristic if the solution is confusing or disappointing [80];
- **Interpretation** – The interface implementation should make reasonable guesses about what the user is trying to do. This heuristic is exceptionally important regarding voice interaction technologies. The ability to guess the next ideas of a conversation allows the system to maintain a more “natural” interaction [81];
- **Cultural propriety** – According to this heuristic, interfaces should match the user's social customs and expectations. In this context, the design of voice interfaces should consider the specific lingos' usage [81].

4.2.3 Specific Heuristics for Older Persons

Digital products should be designed in a way that the needs of people of all ages are met. This requires attention to subgroups of individuals with particular characteristics and needs such as older persons. Ageing is associated with a deterioration of the normal functioning at different levels: sensory function, mobility, balance, memory, and attention. Moreover, the magnitude of the changes vary within subgroups of older persons, depending, for example, on whether they are healthy and active or suffer from chronic conditions. Based on this premise, Farage et al. [82] proposed a set of general heuristics directly mapped to functional changes associated with age and defined to accommodate changes that occur in the (i) visual, (ii) auditory, (iii) touch and temperature, perception and mobility and balance, and (iv) cognitive functions.

In addition to this generic set of heuristics, some heuristics attempt to combine the specificity of the technology with the specificity of older persons. Kurniawan & Zaphiris [83] proposed a set of 38 heuristics for web design. These were subsequently adapted for mobile interfaces by Díaz-Bossini & Moreno [84] and shrunken to 19 heuristics. Two other authors have also proposed sets of heuristics for mobile [85], [86]. Al-Razgan & Al-Khalifa [85] proposal has 48 heuristics and Silva et al. [86] report 33 heuristics.

A detailed analysis of these set of heuristics against the generic heuristics of the subsection 4.1 and specific heuristics for specific technological supports, suggests that a few could be included in those already presented, but should receive greater emphasis when designing digital products for older persons, namely: Ergonomics/dexterity; Reduced memory load/cognitive load/cognition (i.e., accommodating changes in cognitive function); Visual Presentation (i.e.,

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accommodating changes in visual function); Auditory Presentation (i.e., accommodating changes in auditory function). Also, additional ones should be considered:

- **Preferable gesture**, i.e., changes in fine motricity require that the older person can choose from a range of gestures the one that he/she is more comfortable with or preferred for interaction with the digital solution;
- **Accommodating altered touch and temperature perception and restricted mobility and balance**, i.e., accommodating age and disease-related changes in the ability to detect touch and temperature as well as changes related to mobility and balance.

4.2.4 Proposal of a Set of Heuristics to Use in SHAPES

Considering the generic set of Heuristics [15] and the specific ones derived from the accessibility domain, the specific technological supports and the older persons' specificities, the following SHAPES Heuristics are proposed:

#1 **Visibility (information) of system status** – The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

#2 **Match between system and the real world** – The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

#3 **User control and freedom** – Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

#4 **Consistency and standards** – Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

#5 **Error prevention** – Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

#6 **Recognition rather than recall** – Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another.

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Instructions for use of the system should be visible or easily retrievable whenever appropriate.

#7 **Flexibility and efficiency of use** – Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

#8 **Aesthetic and minimalist design** – Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

#9 **Help users recognize, diagnose, and recover from errors** – Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

#10 **Help and documentation** – Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

#11 **Equitable use** – The design must useful and marketable to people with diverse abilities.

#12 **Perceivable information** – Information and user interface components must be presentable to users in ways they can perceive.

#13 **Operable user interface and navigation** – User interface components and navigation must be operable.

#14 **Ergonomics**, **low physical effort and size and space for approach and use** - The design must be used efficiently and comfortably and with a minimum of fatigue and an appropriate size and space must be provided for approach, reach, movement, manipulation, and use regardless of user's body size, posture, or mobility.

#15 **Motivation and engagement** – Stimulating attention, interest, personal innovativeness, and effort expectancy should be addressed.

#16 **Pleasure, emotion, fun and amusement** – Emotions, fun sensation, satisfaction, and gratification levels should be considered, and confusing or disappointing solutions should be avoided. A Pleasurable and respectful Interaction with the User should be provided so that the user does not feel uncomfortable while using it.

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#17 **Privacy and security** – The system should assure the protection of the user personal and private information, preserving confidentiality, integrity and availability of the information.

#18 **Interpretation** – The interface should make reasonable guesses about what the user is trying to do, namely when voice interaction technologies are being used. The ability to guess the next ideas of a conversation allows the system to maintain a more "natural" interaction.

#19 **Personalization and customization** – The application should provide the user with the possibility of setting and customizing options.

#20 **Cultural propriety** – Regarding this heuristic, interfaces should match the user's social customs and expectations. In this context, the design of voice interfaces should consider the specific lingos' usage.

#21 **Preferable gesture** – For interface-gesture interaction, the digital solution should provide the opportunity to choose the preferable for interaction.

#22 **Accommodating altered touch and temperature perception and restricted mobility and balance** – Interfaces should be designed so that they can accommodate decreased thresholds of detection of touch and temperature as well as changes related to mobility and balance.

4.3 Standards

Some of the principles and heuristics mentioned in the previous sections have been validated internationally; in several cases they are present in International Standards. In this section the most relevant International Standards in the area are presented, organized according to the following topics: user interface design (including usability), accessibility, multimodal technologies and ageing (Table 9).

Table 9 International Standards: user interface design, accessibility, multimodal technologies and ageing

Topics	Standards
User Interface Design (including usability)	ISO 9241-210:2019: Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems
	ISO 9241-110:2020: Ergonomics of human-system interaction — Part 110: Interaction principles

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	ISO 9241-11:2018: Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts
	ISO/TR 16982:2002: Ergonomics of human-system interaction — Usability methods supporting human-centred design
	ISO/IEC 25010:2011: Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — System and software quality models
	HHS Web Standards and Usability Guidelines (U.S. Department of Health & Human Services)
	Material Design (Google®)
	Human Interface Guidelines (Apple®)
	Fluent Design System (Microsoft®)
Accessibility	ISO/IEC Guide 71:2014: Guide for addressing accessibility in standards
	ISO 9241-20:2008: Ergonomics of human-system interaction — Part 20: Accessibility guidelines for information/communication technology (ICT) equipment and services
	ISO/IEC 40500:2012: Information technology — W3C Web Content Accessibility Guidelines (WCAG) 2.0
	ISO/IEC 30071-1:2019: Information technology — Development of user interface accessibility — Part 1: Code of practice for creating accessible ICT products and services
	ISO/IEC 29138-1:2018: Information technology — User interface accessibility — Part 1: User accessibility needs
	ISO/IEC 13066-1:2011: Information technology — Interoperability with assistive technology (AT) — Part 1: Requirements and recommendations for interoperability

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	ISO/IEC 29136:2012: Information technology — User interfaces — Accessibility of personal computer hardware
	ISO 9999:2016: Assistive products for persons with disability — Classification and terminology
	ISO 9241-171:2008: Ergonomics of human-system interaction — Part 171: Guidance on software accessibility
	European Accessibility Act: Improving the accessibility of products and services in the single market
	Directive (EU) 2016/2102 of the European Parliament and of the Council of 26 October 2016 on the accessibility of the websites and mobile applications of public sector bodies
	EN301 549 V2.1.2 (2018): Accessibility requirements for ICT products and services
	User Agent Accessibility Guidelines (UAAG) for browsers, media players, and other "user agents"
	Authoring Tool Accessibility Guidelines (ATAG) web standard
Multimodal technologies	ISO 13482:2014: Robots and robotic devices – Safety requirements for personal care robots
	ISO 9241-154:2013: Ergonomics of human-system interaction — Part 154: Interactive voice response (IVR) applications
	ISO/IEC 2382:2015: Information technology — Vocabulary
	ISO/IEC 30122-1:2016: Information technology — User interfaces — Voice commands — Part 1: Framework and general guidance
	ISO/IEC 30122-2:2017: Information technology — User interfaces — Voice commands — Part 2: Constructing and testing

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	ISO/IEC 19794-13:2018: Information technology — Biometric data interchange formats — Part 13: Voice data
Ageing	ISO/TC 314: Ageing societies (*under development*)

4.4 User Interface Design Recommendations

After an analysis of recognized, accepted, and applied heuristics proposed by different authors, the set of 10 heuristics of Nielsen emerged as the most appropriate Generic Set of Heuristics to Support User Interface Design within SHAPES. For the purpose of the present deliverable, this set of heuristics was complemented with additional heuristics considering the requirements of SHAPES platform and respective digital solutions: accessibility driven heuristics, specific heuristics for specific technological supports (e.g., web, mobile, multimodal) and specific heuristics for older persons, resulting in 22 heuristics to be considered in the development of the SHAPES platform and digital solutions. To consolidate this set of heuristics additional opinions were gathered, including the ones pertaining to the SHAPES partners working in work package (WP) 5.

Each of these heuristics (H) is linked to a set of practical recommendations, presented in Table 10, namely for web (Web), mobile (Mob) and multimodal (Mul) supports. Furthermore, it is also identified in Table 10 whether each recommendation should be considered for users in general (G) or whether it is particularly relevant when users are older persons (OP). The recommendations in Table 10 are organized in an ascending way, according to the number of each heuristic (i.e., from recommendations that are mapped to Heuristic 1 - #H1, to recommendations that are mapped to Heuristic 22 - #H22).

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Table 10 SHAPES User Interface Design Recommendations

Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
1. The system should keep users informed of what is happening, through efficient feedback for all user actions and within a reasonable timeframe, so that users can plan their next action. Provide legible feedback, maintaining a standard and comprehensible appearance, and providing clear information to support the users' decision making at the most fundamental level, in order to support their exploration/usage and to avoid eventual obstacles [15], [44], [85], [87]–[93].	x																						x	x	x	x	x
2. The system should target a feedback delay below 430 ms (accounting for the natural dwell time) [94].	x																						x	x		x	x
3. The system should include visual, auditory and tactile signals that give distinctive feedback to the user, providing informative feedback and managing users' attention to what is really important at each precise moment [64], [81], [101], [102], [86], [87], [95]–[100].	x					x		x				x	x		x								x	x	x	x	x
4. The system interface should be clear relating to what actions are available at any given point of its usage, avoiding the users' confusion [44], [85], [87]–[89].	x					x		x															x	x	x	x	x
5. The system should provide human-computer dialogue, predicting labels associated with screens, texts and objects, preserving the natural cognitive relationship between the user and the system and an easier task accomplishment [85], [87], [103].	x	x				x						x											x	x	x	x	x

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
6. The system should be clear relating to (i) its behaviour, enabling the users to access further information related to the system performance, and (ii) to what it can do, so the users can understand what they can do by using it and what kind of feedback they will receive [85], [87], [90].	x				x				x	x													x	x	x	x	x
7. The system should provide extra and bolder navigation cues, as well as location of the current screen [83].	x																						x	x	x	x	x
8. The system should avoid deep hierarchy and group information visually into meaningful categories (e.g., make good use of colour, text, topics) [83], [86].	x							x															x	x			x
9. The system should provide information related to the level of battery, time and date, signal of contact/Wi-Fi [85, pp. 416-418].	x																							x			x
10. In voice interaction, the system should always keep the user informed about what is going on through appropriate feedback within a reasonable time, providing, if necessary, confirmation of actions [100, p. 220].	x											x			x	x									x	x	
11. In voice interaction, the interface should inform users about the results of their actions and the interface's status [81].	x																								x	x	
12. In feet interaction, on-screen interfaces should provide a direct spatial representation of the movement of the feet. However, the lack of visibility of the feet is somewhat compensated by the user's proprioception: the inherent sense of the relative positioning of neighbouring parts of the body. Therefore, even though users are not able to see their feet they still know	x													x											x	x	

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
where they are in relation to their body [101, p. 397].																											
13. In feet interaction, help the players to maintain visual independency and focus their attention on the exergame activity or task rather than on how to control the game [103, p. 8].	x					x		x						x	x										x	x	x
14. The system should use phrases, words and concepts that are familiar to the user, rather than system-oriented terms, and should be grounded in real conventions, delivering an experience that matches the system and the real world (e.g., symbols and controls), avoiding the users' cognitive load and predicting learning mechanisms to support the users' interaction [15], [88], [89], [91], [92], [95], [101], [107].		x				x		x															x	x	x	x	x
15. The system's elements that reflect material objects should be similar to those objects from the real world (alignment to the object's version of reality) [108].		x																					x	x		x	x
16. The system should eliminate unnecessary complexity and be based on the target audience's native language [15], [88], [92], [101], [107].		x		x								x											x	x	x	x	x
17. The system should match the most relevant social norms, ensuring that the experience is delivered according to what the users expect and to their cultural and social context [90, p. 3].		x									x									x			x	x	x	x	x
18. The system should use natural clues, efficient interaction language, and visual representations that are disseminated in real world through visual languages, providing simple and clear language [83], [84], [87], [89].		x																					x	x	x	x	x

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
19. The system should highlight the important information [83], [84].		x						x				x											x	x	x	x	x
20. The system should concentrate the information mainly in the centre [83], [84].		x																					x	x	x	x	x
21. The system' screen layout, navigation and terminology should be simple, clear and consistent [83]–[85].		x	x	x				x					x										x	x	x	x	x
22. The system should provide the options/information in a logical sequence [85, p. 416-418].		x																					x	x	x	x	x
23. The system' icons should be simple and meaningful [83], [84], [86].		x						x															x	x	x	x	x
24. For moving systems this may include adopting socially accepting human-system distances and gestures, by using nonverbal actions to build interactive understanding with users [109] through vocal speech, eye contact, facial expressions.		x																							x	x	
25. In voice interaction, the interface will fit the way each user group works and thinks [81].		x										x													x	x	
26. In voice interaction, keep the dialog simple [100, p. 14].		x										x				x									x	x	
27. In voice interaction, the wording of options/text should be aligned with the way users think [100, p. 16].		x																							x	x	
28. In voice interaction, abide by natural turn-taking protocol [100, p. 17].		x												x	x	x											
29. In feet interaction, using the feet for tasks for which we normally think of as being performed by the feet can possibly yield better performance, at least on a neurological and cognitive level [103, p. 11].		x																							x	x	

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
30. The system should offer different user control options for the interface: (i) in order to avoid the occurrence of errors by the user or the system itself; (ii) providing clearly marked "emergency exits" when users choose system functions by mistake; (iii) supporting undo and redo operations and offer the ability to go back or forward screens; (iv) and offering the ability to pause, resume, restart, or end activities [15], [44], [85], [91], [92], [95], [103].			x		x																		x	x	x	x	x
31. The system should ensure that the "Back" button behaves predictably [86, p. 3240].			x																				x	x	x	x	x
32. The system should support user control and freedom, allowing for alternative and flexible flows of interaction [81], [83], [86], [89].			x				x			x													x	x	x	x	x
33. The system should allow the user to interrupt if routed to a path they do not wish to follow [100, p. 220].			x																						x	x	
34. The system should include functions allowing the user to easily leave an unwanted state or interaction (support easy undo and redo) [111].			x																				x	x	x	x	x
35. In voice interaction, the interface will allow the user to perceive that they are in control and will allow appropriate control [81].			x																						x	x	
36. In voice interaction, offer alternative modalities for error correction [100, p. 18].			x				x		x																x	x	
37. The system should maintain personalized style guides to support consistency [44].				x				x															x			x	

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
38. The system should present content and actions in a consistent and standard way, so that users do not have to ask themselves if different words, situations or actions mean the same thing [15], [64], [85], [91], [92], [96], [98], [99], [112], [113].				x																			x	x		x	x
39. The system should adopt colour standards, typography, positioning, page titles, among others, in order to facilitate the user's navigation in the interface [86], [91].				x				x															x	x		x	x
40. The system should present dynamic content carefully: (i) using an active voice, from short and direct phrases, appropriate grammar and ensuring that abbreviations and acronyms are spelled out the first time they are mentioned on each page; (ii) avoiding attempts at humor, metaphors, vague and ambiguous terms, first-person phrases, violent, negative or degrading terms, psychologically threatening terms (for example, "illegal", "invalid" and "abort"); (iii) and careful choosing the words used in labels, menus titles, menu options, icons and data fields, avoiding the term "hit", using "press" or "click" instead [44], [88], [100], [101].				x																			x			x	
41. The system should provide the date of creation of the content, together with the date of update for each page, and the date of any technical maintenance [88].				x																			x			x	
42. The system should use similar names for similar things and use different terms for different things [44].				x		x																	x			x	
43. The system should include buttons and other actionable elements that should be at least 9mm high by 9mm wide, ensuring that buttons are large enough to				x		x																	x	x		x	x

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
easily see the image or text on them [64], [83], [85], [96], [98], [99], [112], [113].																											
44. Since smartphones have a limited width, the system should be designed in a way that: (i) the users will not have to scroll horizontal; (ii) the buttons are visually differentiated from other actionable element; (iii) the elements related to functionality and content understandability are positioned above the scroll line to minimize missed information, allowing users to clearly identify when screens extend beyond the scroll line; and (iv) the user interface elements are not smaller than the smallest average finger pad (1cm - 0.4" - in diameter or a 1cm x 1cm square) [64], [96], [98], [99], [112], [113].				x																				x		x	
45. The system' essential information or features, such as a label, instructions, or sub-controls should be placed below an interface element that can be touched [64], [72], [73], [96], [98], [99], [112], [113].				x								x											x	x	x	x	x
46. The system' main menu should be easily locatable and identifiable. Standard design conventions would likely lead most users to look for a menu on the top, left-hand side of the screen. A collapsed menu is often associated with the three-bar "hamburger" icon that the users are expected to be familiar with. The system should display marked hamburger menus, so that screen readers can identify them, instead of pull down menus [64], [83], [96]–[99], [113], [114].				x								x											x	x		x	x

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
47. The system should ensure consistency, namely between the user interface and the device behaviour/response, by having similar events causing similar outcomes [44], [88], [89], [95], [115].				x		x																	x		x	x	x
48. The system should strive for consistency in workflow, functionality, appearance and terminology to facilitate the user's next interaction [111].				x														x					x	x	x	x	x
49. The system should ensure a clear and appropriate information presentation. The system should provide an integrated presentation of the information retrieved from multiple sensors (e.g., smartwatch) [89, p. 257].				x																					x	x	
50. In robotics, any system response should be given consistently by several output channels [110, p. 402].				x																					x		x
51. In robotics, the system graphical user interface (GUI) and button elements should be sufficiently big in size so they can be easily seen and used (> finger size (~20mm) in case of touch screen, buttons). GUI and button elements should have both easy to understand and big enough graphical and textual information about their meaning [110, p. 402].				x								x	x	x											x		x
52. The system GUI and button elements should be arranged in a consistent and clearly spaced way [110, p. 402].				x								x	x	x											x		x
53. The system should have a consistent interface [44], [81], [85], [88].				x		x																	x	x	x	x	x
54. The interface will be free from errors [81].					x																		x	x	x	x	x

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55. The system should have mechanisms to prevent, detect and correct users' errors, reducing the possibility of failure, so error-prone conditions should be eliminated, instead of helping the users to recover from possible mistakes using the interface [15], [44], [73], [91], [92], [95], [104], [116].					x				x	x													x	x	x	x	x
56. The system should provide mechanisms to assist the user in carrying out the tasks, avoiding inappropriate choices or errors. For example, the system should provide the option of confirmation before committing the user to any (critical) action such as deletion [15], [44], [85], [91], [92], [116].					x																		x	x		x	x
57. The system should organize its elements to minimize errors. The most used and accessible elements should not be close to the most dangerous and protected elements. The system should provide warnings about hazards and errors, ensuring fail-safe features [101].					x																		x			x	
58. The system should ensure that relevant information and actions are presented to the users and that they understand and achieve them, avoiding incorrect decisions, and ensuring efficient correction, preventing, and recovering from possible device errors [87], [89], [90].					x																				x	x	
59. The system' graphical interface design and the organization should help prevent errors. Errors and unclear situations for the user should be avoided by guiding the user to select from meaningful alternatives [85], [104].					x																			x		x	x

Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
60. The system should provide important functions at top of the screen to avoid mistake touches, and ensure that the most important or frequently needed functions are accessed directly [85, p. 416-418].					x	x																		x			x
61. In voice interaction, adopt speaking style that minimizes error, and minimize acoustic confusability of vocabulary [100, p. 11].					x			x																	x	x	
62. The system' search engines should cater for spelling errors [83, p. 131].					x																		x	x	x	x	x
63. In feet interaction using the whole of the foot sole makes it easier to hit targets. Leave enough space between targets as to prevent accidental activation [101, p. 397]. Increasing distance of targets within reasonable limits increases interaction time, but does not increase error [112, p. 271]. Larger buttons and interaction points are needed, once that the users use the entire surface of their foot and fine-level control with one's feet is much more challenging [113, p. 10].					x							x	x	x											x	x	
64. In feet interaction, relating to movement direction, forward and backward foot movements are more tiring than left and right ones [103, p. 7]. Forward movement is less error prone to use, and backwards and backwards-diagonal interaction are hardest to use [112, p. 271].					x		x							x		x									x	x	
65. The system should minimize the user's (short-term) memory load, making objects, actions and options visible and easily located, and by providing real-time contextualized, relevant, appropriated, and						x																	x		x	x	

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useful information to the users' tasks [15], [44], [89], [90], [92], [95].																											
66. The system should be easy to learn, both for the user to start using it quickly, and to remember it easily, even after an inactive period: (i) instructions should be visible or easily retrievable; (ii) header tags should be used in the text allowing to move consecutively from one header level to the next; (iii) a link strategy should be used, such as describing the link before inserting it, and also offering visual cues, such as icons, underlining and highlighting when hovering [15], [44], [91], [92], [100].						x																	x			x	
67. The system should consider forms in relation to screen readers and offer transcriptions for audio resources, such as subtitles for video. Label the fields and describe the screen readers using tags [100].						x																	x			x	
68. The system should use alternative text (ALT text) in images, as well as explain images and graphics [83], [84], [88], [100], [114].						x		x				x											x	x		x	x
69. The system should group related objects and functions by user task or work activity [44], [85], [101].						x		x															x	x		x	x
70. The system should allow the users to easily recognize user functions and the system options through interaction, affordances, and visible features, saving recent actions/interactions, allowing them to recover short term memory and with that help the users to interact with the system [90], [95].						x																			x	x	

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71. The system should have objects, actions and options visible to the user, so that the user does not have to remember information from another part of the dialogue [15].						x																	x	x	x	x	x
72. The system should avoid window occlusion, providing the most relevant information at the viewport [84], [89].						x		x															x	x	x	x	x
73. The system should provide clear confirmation of target capture, which should be visible to older persons who should not be expected to detect small changes [83, p. 131].						x																	x				x
74. The system should avoid double click. Older persons should not be expected to do it [83], [84].						x																	x	x			x
75. The system should provide clear links with: (i) differentiation between visited and unvisited links; (ii) clear named and labelled links and no link with the same name should be used in a different page; (ii) in a bulleted list, avoiding tightly clustered [83, p. 131].						x																	x				x
76. The system should provide ample time to read information, avoiding the use of interaction timeouts [81], [83], [84], [86].						x	x																x	x	x	x	x
77. The system should reduce the demand on working memory by supporting recognition rather than recall and provide fewer choices to the user [83], [85], [86]. Recognition is important since errors degrade usability and lead to user frustration [100, p. 220].						x	x	x	x	x													x	x	x	x	x
78. The system should promote recognition in both the content and the interface (e.g., allow users to save information, provide access to areas or						x																	x	x		x	x

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pages recently visited, include a search engine) [119].																											
79. The system should provide clear, understandable and labelled icons, ensuring that there are visual cues, helping the older persons to know there is more content in a page, and ensuring that it is obvious which item is clickable and which is not [84], [85].						x																		x			x
80. The system should ensure an easy data entry process, namely ensuring that the keypad is separated into numbers and letters for data entry [85].						x																		x			x
81. The system should ensure that buttons and icons enlarge when the rest of the text size is increased, and that there is enough space between buttons to prevent hitting multiple or incorrect buttons [85, p. 416-418].						x																		x			x
82. The system should ensure focus on one task at a time instead of requiring the user to actively monitor two or more tasks, and clearly indicate the name and status of the task at all times [86, p. 3240].						x									x									x			x
83. The system should avoid the use of animation and fast-moving objects, only providing graphics that are relevant and not for decoration [83], [84], [86].						x		x															x	x		x	x
84. The system should be flexible, allowing the users to manipulate information according to their mental model [86], [87].						x	x																	x	x	x	x
85. In the absence of a companion screen display, listed information should be kept short and concise, containing only						x																			x	x	

Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
information necessary to the action being performed [100, p. 220].																											
86. Users want speed and efficiency. The fewer the number of steps that user-system dialog requires, the greater the perceived efficiency of the interaction with the system [100, p. 220].						x							x	x											x	x	
87. The system should be designed based on the principle of flexibility, offering different ways to perform the same task. This flexibility can occur, e.g., through shortcut keys and different menu options [44], [91], [92], [101].							x																x			x	
88. The system should support both inexperienced and experienced users, by using accelerators that can speed up the interaction of both user profiles (e.g., provide shortcuts to perform familiar actions) [15], [92], [95].							x																x		x	x	
89. The system' navigation options should allow customization of default font size (preferable on page controls), the magnification of entire screen, and the magnification lens view under user's finger [96], [98], [99], [112], [113], [120].							x																	x		x	
90. The system should provide a proper keyboard, allowing the users to their inputs [73], [96], [98], [99], [112], [113], [120].							x						x										x	x	x	x	x
91. The system should allow the users to customize the experience, by providing global controls and allowing them to manipulate the information displayed and its storage. The system should allow users to ignore or dismiss undesirable features [89], [90].							x																		x	x	

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92. The system should allow users to tailor frequent actions [121].							x																x	x	x	x	x
93. The system should allow users to customize specific functions, based on their differing needs (e.g., provide a selection of units) [15].							x																x	x		x	x
94. The interface will fit individual tasks within whatever modality is being used: auditory, visual, or motor/kinaesthetic, accommodating a wide range of individual preferences and capabilities [81].							x						x						x				x		x	x	
95. The system should ease complex tasks using progressive disclosure, indicating preferred actions or next steps or locating controls near the objects that users want to control [111].							x											x					x	x	x	x	x
96. The system should facilitate the user's accuracy and precision [122].							x																x	x	x	x	x
97. The system should provide adaptability to the user's pace [122].							x																x	x	x	x	x
98. The system should place items and information consistently to improve the user's efficiency of use [123].							x																x	x	x	x	x
99. In voice interaction, the interface should communicate as efficiently as possible [81].							x	x				x													x	x	
100. In voice interaction, the interface should allow the user to adjust the design for custom use, operating at a time suitable to the user, and providing additional assistance as needed or requested [81].							x												x						x	x	
101. In voice interaction, offer alternative input modalities beyond keyboard [73], [103].							x				x		x										x	x	x	x	x

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102. In feet interaction, for people in wheelchairs and crutches or with other disability or impairment of the lower limbs, it will be difficult or even impossible to use such devices. Also, short people might find difficult reaching far targets on the floor if sitting on a highchair. Provide input alternatives for these users [103, p. 9].							x				x			x											x	x	
103. In feet interaction, tapping and kicking are both feasible, but users have a slight preference for tapping: use tapping for more frequent actions. When tapping, people prefer toe taps. Use toe taps for most common actions, then whole foot taps, then heel taps [112, p. 271].							x							x		x									x	x	
104. In feet interaction, people use both feet equally well - any effect of foot dominance is small. This means the user preference to alternate feet is supported without increased time or errors [112, p. 271].							x							x		x									x	x	
105. In feet interaction, promote step length variation by offering variation in exergame tasks [103, p. 7].							x				x			x		x			x						x	x	x
106. In feet interaction, elicit variation in movement direction during the gameplay [103, p. 8].							x							x											x	x	x
107. The information provided in the system should be simple, concise and to the point, facilitating its understanding, and should not display irrelevant or unnecessary information, because this can reduce the user's focus on important information [15], [44], [81], [83], [84], [89], [91], [92], [101].								x															x	x	x	x	x

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108. The information should be organized and presented in the system according to its importance, ideally with an index, navigation icons, navigation trails and site map, favouring an ideal navigation experience [44], [88], [101].								x					x										x			x	
109. The system should keep clutter to a minimum [124].								x															x	x	x	x	x
110. The system should provide clearly visible and unambiguous means of navigating to other content [124].								x															x	x	x	x	x
111. The system should provide intuitive and realistic interfaces and interactions [116].								x															x			x	
112. The system should have a good contrast between the background colour and the colour elements, ensuring readability and perceptibility (e.g., coloured text on coloured backgrounds should be avoided). Avoid pure white background screens or change rapidly in brightness between screens or contrast backgrounds. The system' content should not all be in colour alone (colour here is denoted by all colours other than black and white). In particular, the system should give preference to pastel tones over bright tones, avoiding blue and green tones. Avoid using blue, green and yellow in close proximity [44], [83], [84], [86], [88], [92], [100].								x															x	x		x	x
113. The content of the system interface should be readable, so the font size should be large enough for all users. Provide a font size of, at least, 12px, to be readable by the								x				x											x			x	

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largest possible number of users [44], [88], [100], [101].																											
114. The system should maintain a typographic and font size pattern for the interface [44], [88].								x															x			x	
115. The system should avoid a sophisticated or attractive design without a real purpose, with a minimalist, simple, and clear user interface [44], [81], [89].								x															x		x	x	
116. The system interface should avoid automatic audio or video playback [88].								x															x			x	
117. The system should use colours in a conservatively way, limiting the maximum number of colours in use to four [83], [84], [86].								x															x	x			x
118. The system' text should be left justified and text lines should be short in length. The text should be spaced between the lines and the main body of the text should be in sentence case. Avoid moving text avoiding capital letters and ensure clear large headings [83, p. 131].								x															x				x
119. The system should use San Serif type font, for instance, Helvetica, Arial of 12-14px, avoiding fancy font types [83], [86].								x															x	x			x
120. The system should ensure an aesthetical user interface, by using pictures and/or graphics purposefully and adequately to minimize user interface clutter and avoid extraneous details. Ensure appealing embodiments (size, shape, colour, materials, facial features and motion) [125], prioritising, in the case of robots, those with human-like features. Targets should be at least 14mm square [86], [89].								x				x												x	x	x	x

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121. The system should provide information easy to read, skim (or) and scan, providing links and buttons clearly visible and distinguishable from other user interface elements and there should be sufficient white space to ensure a balanced user interface design [86, p. 3240].								x																x			x
122. In voice interaction, choose persona judiciously [100, p. 19].								x			x														x	x	
123. The system should help users to recognize, diagnose and recover from errors, by allowing them to reverse actions [15], [44], [81], [89], [92], [95].									x														x		x	x	
124. The system should provide clear feedback and when presenting error messages they should be simple, easy to follow, positive and expressed in simple language, so that the user can understand it [15], [44], [83], [86], [92], [95].									x														x	x	x	x	x
125. The system error messages should accurately indicate the problem and constructively suggest a solution [15], [44], [92].									x														x			x	
126. The interface will make actions recoverable [81].									x																x	x	
127. In the case of robotic solutions, the system should offer information on its internal status using LEDs, speech, or visual interface in order to indicate errors [126].									x																x	x	
128. In voice interaction, optimize work style for error correction [100, p. 11].									x																x	x	
129. The system should give specific and clear instructions, make help and documentation available, focused on the user' task, list concrete steps to take, be										x													x	x	x	x	x

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brief and include all accessibility features [15], [92]. Help and documentation available should be easy to search. Remember that it is better to prevent an error than to recover from it [15], [86], [92], [127].																											
130. The system should provide help that is easily located, specific to the task at hand and worded to guide through the necessary steps towards a solution [128].										x													x	x	x	x	x
131. The system instructions should be appropriate, understandable and positive [101], [116].										x													x			x	
132. The system should provide effective suggestions and comments during and after the completion of an action [83], [101], [116].										x													x			x	x
133. The system should avoid scheduled responses and complex feedback and help interactions. Feedback should include enough information, so users can understand the results and be confident that the command worked or are able to understand why it did not work. Provide enough information for users to make reliable decisions about the status of their interaction course, and about the possibilities or alternatives. If necessary, provide supplementary information. Audio and/or video feedback/help/tutorials should also be considered [44], [116].										x													x			x	
134. The system should provide instructions for custom touchscreen and device manipulation gestures [96], [98], [99], [112], [113], [120].										x														x		x	

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135. The system should support efficient invocation, enabling its features/services whenever the users' request (e.g., request for help to an artificial intelligence system), and should provide help and additional information, to assist the users during the interaction, allowing users to easily deepen information [90], [95].										x															x	x	
136. The system should provide a site map [83, p. 131].										x													x				x
137. Make the design appealing to all users, avoiding segregating or stigmatizing any users, and providing the same means of use for all (identical whenever possible or equivalent when not, e.g., be useful and appealing to seniors, caregivers and health professionals). Provide sufficient alternatives for the needs of different users, namely in what concerns privacy, security, and safety that should be equally available to all [44], [72], [91], [92], [101], [122].											x												x	x	x	x	x
138. The system should have an age-appropriate interface for the target user, and be adaptable according to the users' physical and cognitive abilities, and their disability, if any, as well as their level of knowledge in technological interfaces [44], [92], [116].											x												x			x	
139. The system should provide mobility, visual and auditory accommodations, amongst others, providing compatibility with a variety of techniques or devices that people with sensory disabilities [44], [92], [101], [116].											x												x			x	
140. The system should not require interactions that a user cannot perform [129].											x		x										x	x	x	x	x

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141. Make information accessible through different modalities [86, p. 3240].											x													x			x
142. Make it easy for people to change the text size directly from the screen [86, p. 3240].											x													x			x
143. The system should be free of stereotypes and social biases, ensuring a fair and comprehensive usage [90, p. 3].											x									x			x	x	x	x	x
144. The system should accommodate different genders, body types and weights [130].											x														x	x	
145. The system should provide appropriate size and space for approach, reach, manipulation and use, regardless of the user's body size, posture or mobility [122].											x			x									x	x	x	x	x
146. The interface will not overload the user's cognitive, visual, auditory, tactile, or motor limits [81].											x	x	x	x											x	x	
147. The robot should meet the person's needs, be slow, safe and reliable, small, easy to use and have an appearance not too human-like, not patronizing or stigmatizing [130].											x	x		x				x		x					x		x
148. In feet interaction, provide temporal variation in movements by offering adaptive changes in the game speed [103, p. 7].											x			x		x			x						x	x	x
149. Use different modes/formats (pictorial, verbal, tactile) for redundant presentation of essential information, providing compatibility with a variety of techniques or devices used by people with sensory disabilities [72], [73], [101], [122].												x											x	x	x	x	x
150. Provide adequate contrast between essential information and its												x											x	x	x	x	x

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
surroundings, maximizing "legibility" of essential information [72], [73], [122].																											
151. Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions) [72], [73], [122].												x											x	x	x	x	x
152. Important information should be within the system's path for screen readers to find it [114].												x											x			x	
153. Depending on the target user, the system should provide sign language interpretation for all audio or video materials and captioning [88].												x											x			x	
154. The design should be capable of effectively providing necessary information to the user, regardless of ambient conditions or the user's sensory abilities [72, pp. 2010–2052].												x											x			x	
155. The system should predict alternative content, ensuring accessible automatically-specified content and helping the users to manage it for non-text content, ensuring that the accessibility of the system information is preserved [127].												x													x	x	
156. The system should be compatible with glasses, hearing aids, walkers, and other assistive devices [131].												x												x			x
157. Facilitate the operator's knowledge of the robot's activities [89, p. 257].												x													x		x
158. In voice interaction, the system should speak in a natural way and adopt human-to-human speech conventions. This acts to increase the interaction flow and comprehension [100, p. 220].												x	x												x	x	
159. In feet interaction, sensing techniques should be robust to changes in												x		x											x	x	

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
foot pitch and external rotation of the feet with sideways motion [112, p. 271].																											
160. Users should have enough time to read and use the content and can easily navigate, find content, and determine where they are [73], [129].													x										x	x	x	x	x
161. Content does not cause seizures and physical reactions [73].													x										x	x	x	x	x
162. If the system requests additional computer applications, working links should be provided to download the application [88].													x										x			x	
163. The graphic files of the system should be marked with a "mouse over" to indicate the presence of the graphic content [88].													x										x			x	
164. The system should include buttons and other actionable elements that should not be too sensitive [96], [98], [99], [112], [113], [120].													x											x			
165. The system should inform the users about features/services adds or updates, avoiding disruptive user interface updates and adaptation that deeply change the system behaviour [90, p. 3].													x												x	x	
166. The system should predict structured content to enhance navigation and editing, providing content text-search [127].													x												x	x	
167. Provide choice in methods of use and facilitate the capabilities of each user [72, pp. 2010–2052].													x												x	x	
168. Provide adaptability to the user's usage pace [72, pp. 2010–2052].													x										x				x
169. In Robotics, enable the operator to understand the robot's status: (i) no change													x												x		x

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
in system state should be performed without notifying the user and buttons should provide tactile or other feedback on activation; (ii) provide indicators of robot health/state (e.g., camera being used, position(s) of camera(s)); (iii) and allow self-inspect the robot's body for damages or entangled obstacles [87], [89], [115].																											
170. In voice interaction, the interface will have the highest possible fidelity, allowing the users to perform a task accurately [81].													x												x	x	
171. In feet interaction, appropriate space and size should be considered: (i) for cursor feedback the target angular size should be at least 22.5°, two target levels is feasible with radial size 10cm, and the target angular size should be much greater than 45° (a conservative recommendation is 90°); (ii) for tap and kick interaction, a conservative estimate for an appropriate interaction radius is 20 cm (for tap) , and 30 cm at the front and 25 cm in radius at the back (for kick). [112, p. 271].													x												x	x	
172. Provide adequate space for: (i) making the user reach to all components comfortable for any seated or standing user (ii) allowing the use of assistive devices or personal assistance; (iii) accommodating variations in hand and grip size; (iv) and providing a clear line of sight to important elements for any seated or standing user [72], [79], [122].														x									x	x	x	x	x
173. Create buttons large enough to support targeted mouse movement [44], [101].														x									x			x	

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
174. The system should include buttons and other actionable elements that should be surrounded by a reasonable inactive space. If the items are too close, the user will not be able to choose a single one [96], [98], [99], [112], [113], [120].														x										x		x	
175. The design should be used efficiently and comfortably and with a minimum of fatigue in case of physical activities for older persons [72, pp. 2010–2052].														x									x				x
176. Useful elements should be accessible and hazardous elements are sequestered or eliminated [72], [132].														x									x				x
177. Minimize repetitive actions and sustained effort, using reasonable operating forces and allowing the user to maintain a neutral body position [72, pp. 2010–2052]. [72], [79], [122].														x									x	x	x	x	x
178. People with motor impairment, and in wheelchairs should be able to operate the system comfortably [133].														x										x			x
179. In Robotics, the device should be easy to use: (i) flexible to suit different applications and allowing patients of different gender and different body types and weights to use the robot; (ii) accommodating additional space for equipment accompanied by the patient; (iii) with appropriate weight so it is not felt by the patient allowing he/she to be able to move it easily (this can be achieved by using backdrivable hardware); (iv) and generating sufficient force to move a patient's limb, being easily movable by an elderly or person with a disability [130].														x											x		x

Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
180. Achieving the dual goals of high-force production capability and back drivability is an engineering challenge in rehabilitation robots [117, p. 3].														x											x		x
181. Adapt human-system distance to facilitate interaction in the case of moving systems, detachable touch-screen and height of social robots designed to be similar to the height of end-users [134]																									x	x	
182. In voice interaction, carefully control the amount of spoken output, e.g., following an open-ended prompt [100, p. 13-18].														x											x	x	
183. In feet interaction, fatigue should also be taken into account when designing interactions where any foot is off the floor (…) when moving the feet across the floor, users preferred dragging the foot to hovering it over the floor [101, p. 397].														x		x									x	x	
184. In feet interaction, the system should preferably provide standing upright actions since (a) users are able to reach farther and by walking towards targets, they can reach indefinitely far targets [103, p. 7]; (b) foot gestures performed whilst standing up only allow for one foot to be off the floor at the same time (except when jumping) - to prevent fatigue, such complex gestures should be limited in time and potentially also space [101, p. 397]; and (c) user should be able to perform gestures that involve using only one foot at a time" [113, p. 10]. It is recommended to use symmetric gestures while standing up and asymmetric gestures while sitting down; and asymmetric gestures are preferable for GUI interactions and symmetric gestures are														x	x	x									x	x	

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
preferable when designing avatar controls [113, p. 10].																											
185. In feet interaction, 60 minutes of continual foot interaction, with occasional breaks, is feasible for users to do with only minor discomfort [112, p. 271].														x	x	x									x	x	
186. In feet interaction, elicit weight shift in users by motivating them to move around a larger physical area and displace their centre of mass [103, p. 7].														x											x	x	x
187. The system should provide supportive and autonomous modes, enabling an efficient usage and the users' attention focus on the main task [87], [89].															x										x	x	
188. The system should stimulate the user's autonomy (feeling agency, acting in accordance with one's goals and values) [135].															x								x	x	x	x	x
189. The system should empower the user's competence (feeling able and effective) [135].															x								x	x	x	x	x
190. The system should enable the user's connection (feeling connected, having a sense of belonging) [135].															x								x	x	x	x	x
191. Procedures should be simple intuitive steps with a slow pace and opportunities for practice.															x								x				x
192. Provide simple instructions into discrete short messages.															x									x			x
193. [Robot User Interfaces] RUI's should be designed to allow tasks to be accomplished, rather than drawing attention to the robot or the interface per se [87, p. 479].															x										x		x
194. The system should indicate aliveness by showing some autonomous																									x	x	

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
behaviour, facial expressions, hand / head gestures to motivate engagement [136], as well as changing vocal patterns and pace to show different emotions.																											
195. In voice interaction, users should be able to maintain their focus on one interface or the link to a second interface (e.g., screen display) should be clear and consistent in operation [100, p. 220].															x	x											
196. Use of devices that bring joy and comfort to customers [137].																									x	x	
197. The system should use visual elements (colour, typography, layout, images, graphics, personified icons) to trigger the user's emotions [138].																x							x	x	x	x	x
198. The system should adopt creative and smart interactions (enable users to smoothly complete an interaction) to sustain the user's positive emotions [138].																x							x	x	x	x	x
199. The system should adopt creative microcopy design techniques to attract users [138].																x							x	x	x	x	x
200. The system should consider emotional design elements to trigger and retain positive emotional responses [138].																x							x	x	x	x	x
201. The system should adopt gamification techniques to address the user's need for fun, enjoyment and pleasure [139].																x							x	x	x	x	x
202. The robot should support the therapy defined by the therapist. In no circumstances should the patient be afraid of the robot [117, p. 3].																x									x		x
203. In voice interaction, the interface will make reasonable guesses about what the user is trying to do, and should behave																x		x							x	x	

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
in a manner such that users can accurately predict what will happen next [81].																											
204. The system should provide provisions for privacy and protection for all users [101].																	x						x			x	
205. The system should enable provisions for privacy, security, and safety equally available to all users [122].																	x						x	x	x	x	x
206. The system should ensure transparency and privacy during the interaction ensuring users fell safe: (i) informing the users about what data is being collected, (ii) providing an alert when the user leaves a secure page; (iii) mentioning explicitly what the data collection procedures are like, and enabling users to activate and deactivate subscriptions and the use of cookies; and (iv) providing informed consent, detailed disclaimers, covering privacy and data protection policies [88], [95].																	x								x	x	
207. Provisions for privacy, security, and safety should be equally available to all users especially to older persons [122].																	x						x				x
208. The system should give users the power to control their data, allowing them to decide what information to share, with whom and for what period of time [140].																	x						x	x			
209. The system should keep the user informed on the collection, use, processing, storage and deletion of their data [140].																	x						x	x			
210. The system should deliver a clear, easy-to-read privacy policy [140].																	x						x	x			
211. The system should enforce privacy as a default setting [140].																	x						x	x	x		

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
212. Alert users of possible hazards through visual and speech cues, integrate emergency stops, especially for robots that navigate and have moving arms [109].																									x	x	
213. The system should learn from the users' interaction: (i) learning with their actions to personalize the experience; (ii) retrieving granular feedback during the users' interaction (e.g., during the interaction with an artificial intelligence system); (iii) and predicting cognitive processing to automatically alternate the interaction mode (e.g., artificial intelligence), avoiding the users' cognitive load [87], [90].																		x							x	x	
214. Provide robot help in deciding which level of autonomy is most useful [89, p. 257].																		x							x		x
215. The system should act in a human-like way, in particular in the case of robots, by providing human-like social cues that facilitate the interpretation of their intentions in order to predict their behaviour, through gaze, gestures and speech [141], in addition to adjustment of speech volume, pitch and rhythm to convey its affective state [142].																									x	x	
216. In voice interaction, spoken messages should be clearly pronounced (volume and speed) and consistent with GUI display. Messages should be repeatable upon user request and every user input should be directly answered by a consistent UI response for acknowledgement (avoid impression of non-reaction) [110, p. 402].																		x							x		x

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
217. In feet interaction, learning mechanisms should be used when developing foot-based systems. The system should recognize when a gesture starts and when it ends, once that the users' feet are constantly touching the surface and can cause inadvertent activation. The problem can be viewed as a gesture recognition problem [113, p. 10].																		x							x	x	
218. The system should allow the user to make changes to the interface according to his preferences and provide to the user the possibility to control the amount of information and the details provided in the feedback [44], [91], [92], [101].																			x				x			x	
219. The system should adopt anticipatory design [143], [144].																			x				x	x	x	x	x
220. The system should enable personalisation (create individualized experience for the user) and customisation (support the user's preferences) [145].																			x				x	x			
221. The system should allow the users to manage preference settings [85], [127].																			x				x	x	x	x	x
222. The system should support personalised push content [146].																			x				x	x			
223. The system should allow the user to choose themes, font sizes, colours and the activation of specific options (e.g., haptic feedback, gestures) [146].																			x				x	x	x	x	x
224. The system should give the user the power to choose, in order to create a personalised experience [124].																			x				x	x	x	x	x
225. The system should adopt gamification techniques, such as creating milestones or providing rewards, to signal positive achievements [147].																			x				x	x		x	x

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
226. The system should not require the user to remember a PIN number. It would be beneficial to use face recognition or fingerprint to sign in.																			x						x	x	
227. Adapted speech prosodic features based on user preferences (e.g., introverted / extroverted users) [148] or the circumstances (sitting, standing) as well as human-system distances in the case of moving systems [149].																									x	x	
228. In voice interaction, the user should be able to choose the UI properties (size, brightness, volume, speed …) to his/her liking [110, p. 402].																			x						x		x
229. In robotics, provide help in choosing robot modality [89, p. 257].																			x						x		x
230. The system should consider the users' social and cultural contexts (e.g., support translation to the user's language) [150].																				x			x	x	x	x	x
231. The system should consider contents that relate to the users' social and cultural contexts (e.g., daily activities, games, music) [150].																				x			x	x	x	x	x
232. The system interface design should consider a careful selection of colours. In certain cultures, certain colours may have a different meaning for each user [44], [88], [92], [100].																				x			x			x	
233. In the case of robots, they should direct their gaze towards the users faces they speak [151], as well as establish comfortable approach and interaction distances with users [152].																											

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
234. In voice interaction, the interface will match the user's social customs and expectations [81].																				x					x	x	
235. The system should consider gestural interaction (gesturing or pointing in the air) [153], [154].																					x				x		
236. For interface-gesture interaction, provide the opportunity to choose the preferable for interaction.																					x		x	x	x	x	x
237. The system should identify preferable gestures as shortcuts to frequent actions [153], [154].																					x				x		
238. Users should feel confident that they can operate the system and take appropriate action if something unexpected happens. The system should predict automatically mode changes – manual/automatic control – through simple gestures or actions (e.g., activate the manual control by touching the joystick of a robot) [87].																					x				x	x	
239. Interfaces should be designed so that they can accommodate decreased thresholds of detection of touch and temperature as well as changes related to mobility and balance [82].																						x			x	x	x
240. The system should consider that the user's sensitivity to touch and pressure declines with age, especially on the hands and feet [82], [155].																						x	x	x	x	x	x
241. The system should consider that the user's mobility, body motion and body flexibility decline with age [156].																						x	x	x	x	x	x
242. The system should consider that the user's static balance and dynamic coordination decline with age [82].																						x	x	x	x	x	x

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Recommendations	H#1	H#2	H#3	H#4	H#5	H#6	H#7	H#8	H#9	H#10	H#11	H#12	H#13	H#14	H#15	H#16	H#17	H#18	H#19	H#20	H#21	H#22	Web	Mob	Mul	G	OP
243. The system should support the user with effective sensory resources in presenting feedback [44].																						x	x			x	
244. Regarding touch and temperature: (i) avoid 3D touch screens; (ii) use supplemental sensory cues to warn of high temperatures; (iii) prefer textured surfaces instead of smooth surfaces to complement the touch feel; (iv) sound alert that a button on screen or computer key has been depressed; (v) and use simple task movements for older adults with tremor [157], [158].																						x		x			x

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5 Usability Inspection Methods

Usability evaluation can be empirical (based on data from real users) or analytical (based on the analysis by specialists / experts of an interactive system and / or potential interactions). Empirical models include test and inquiry methods that will be detailed in chapter 6. Analytical models involve the participation of experts to assess the various aspects of user interaction [159]. Many inspection methods lend themselves to the inspection of user interface specifications that have not necessarily been implemented yet, which means that inspection can be performed early in the usability engineering lifecycle [160], [161].

Inspection methods imply the use of standards, heuristics, or guidelines by experts when performing the inspection.

Heuristics have a dual-use as they can be used both for creating an interface (typically used by designers and developers) and to evaluate its compliance in terms of usability (typically performed by usability evaluators) [163]. Experts have a fundamental role in both cases, as they are key contributors to all stages of development: from product design, development, to evaluation. The design standards and heuristics for the design and development of technology were presented in chapter 4.

The importance of usability standards according to [164], is that it increases the speed and decreases the cost of technological development. Along with providing better consistency, standards also improve the quality of user experience [164].

This chapter describes the procedures of usability evaluation by experts and details a set of principles and procedures to conduct inspection evaluation of usability. It aims to support the work developed by the partners involved in the implementation and/or evaluation of the SHAPES platform and digital solutions.

5.1 Synthesis of Current Procedures and Practices for Usability Inspection Methods

This section is based on the findings from a scoping review of reviews on procedures of usability evaluation by experts, whose study design is presented in chapter 1 (Introduction). The scoping review found 12 reviews (Table 11) that form the basis of the information described in this section regarding experts (i.e. the person conducting the inspection), methods, and instruments to support usability inspection that are detailed in the following sections.

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Table 11 General characteristics of included reviews

Authors and Year	Purpose of the paper/study	Number of studies included in the review
Allison et al. [165]	Review methodologies and techniques to evaluate websites; provide a framework of appropriate website attributes that could be applied to any future website evaluations.	69
Baharuddin et al. [166]	Propose a set of usability dimensions that should be considered for designing and evaluating mobile applications	Not referred
Chuan et al. [79]	Create a set of gesture-specific heuristics that would complement existing general usability heuristics for design and testing of new gestural interaction.	6
Costa et al. [74]	Identify the heuristics and usability metrics used in the literature and/or industry; contribute with a proposal of a set of usability heuristics focused in mobile applications on smartphones, considering the User, Task and Context as usability factors and Cognitive Load as an important attribute of usability.	8
Ellsworth et al. [167]	Provide a revision of methods employed for usability testing on electronic health records (EHRs); evaluate methodological and reporting trends.	120
Fernandez et al. [168]	Analyse which usability evaluation methods have proven to be the most effective in the Web domain.	18
Fernandez et al. [78]	Analyse which usability evaluation methods have been employed to evaluate Web applications over the last 14 years.	206
Fu et al. [169]	Assess the usability of diabetes mobile applications developed for adults with type 2 diabetes.	7

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Hermawati & Lawson [77]	Review the processes that were applied to establish heuristics in specific domains and identify gaps in order to provide recommendations for future research and area of improvements.	70
Hussain et al. [170]	Review the relevant and appropriate usability dimensions and measurements for m-banking applications; propose a set of usability dimensions and measurements for m-banking evaluation.	49
Lim et al. [80]	Identify, study, and analyse existing usability metrics, methods, techniques, and areas in mobile augmented reality learning.	72
Yen & Bakken [171]	Review and categorize health information technology usability study methods; provide practical guidance on health IT usability evaluation.	346

5.1.1 Experts

Only three out of the 12 reviews reported on the number and characteristics of the experts involved in the usability inspection. Table 12 presents the type of technology, the number of experts, and main characteristics of included reviews. Often the reader is not informed of how many experts performed the evaluation or the expertise level and domain experience of those performing the evaluation. Many usability evaluation methods are complex and multifaceted, and experts who have usability and/or local systems expertise are critical for effective evaluation [167].

There is also a great variability on what is considered an “expert” as most reviews failed to provide information on how Human-Computer Interaction (HCI) or usability experts were determined, i.e., whether it was based on formal educational years of experience, profession, or other criteria. Inspection evaluation is heavily dependent on the skills of experts involved in the study; thus, lack of information related to their level of expertise can introduce bias into the evaluation [77].

Great confusion was also apparent in the use of the term "expert", as in some reviews this term refers to the professional with knowledge on the field of use of the technology under development (e.g., a physician involved in the development of a technology for monitoring diabetes) or as the professional with knowledge in usability and user experience (e.g., an HCI specialist assigned to evaluate the interface of the technology for monitoring diabetes). Both experts are valuable and have very different roles as

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each one's expertise is essential to ensure that the technology is not only usable but also adapted to users' needs.

Table 12 Type of technology and evaluators' number and characteristics

Authors and Year	Type of technology	Number of experts	Characteristics of the experts
Allison et al. [165]	Websites: e-Bug or similar educational health websites.	Not reported	Experts in the field of website design
Baharuddin et al. [166]	Mobile applications	2	Usability specialists
Chuan et al. [79]	Gestural interaction	Not reported	Not reported
Costa et al. [74]	Mobile apps (for touchscreen smartphones)	Not reported	Domain experts
Ellsworth et al. [167]	Electronic health records (EHRs)	Not reported	Not reported
Fernandez et al. [168]	Web domain	Not reported	Most studies used graduate students as evaluators
Fernandez et al. [78]	Web applications	Not reported	Web designers or students
Fu et al. [169]	Diabetes mobile apps	3 per study	Medical students Usability experts Mobile device experts Informatics Nurses Community health workers

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Hermawati & Lawson [77]	Not specified	An average of 7 evaluators per study (reported in 32 of the 70 studies included in the review)	Usability practitioners and undergraduate students (reported for just one study)
Hussain et al. [170]	Mobile Banking application	Not reported	Not reported
Lim et al. [80]	Mobile augmented reality	Not reported	Not reported
Yen & Bakken [171]	Health information technology	Not reported	Not reported

5.1.2 Current Usability Inspection Methods

In the scoping review that informed this section, seven inspection methods were identified. These are detailed in Table 13 and comprise the following sections: heuristic evaluation, cognitive walkthrough, task analysis, metaphor of human-thinking, systematic usability evaluation, perspective-based inspection, and guideline review. Most reviews refer to more than one inspection method, as is the case of [170] that refers to the combination of heuristic evaluation and guideline review. In addition to the inspection methods that were identified in the scoping review, others were not detected but are widely described in the literature, namely consistency inspection, and formal usability inspection.

Table 13 Usability inspection methods reported in the included reviews

	Allison et al. [165]	**Baharuddin et al.** [166]	**Chuan et al.** [79]	**Costa et al.** [74]	**Ellsworth et al.** [167]	**Fernandez et al.** [168]	**Fernandez et al.** [78]	**Fu et al.** [169]	**Hermawati & Lawson** [77]	**Hussain et al.** [170]	**Lim et al.** [80]	**Yen & Bakken** [171]

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Guideline review	Perspective-based inspection	Systematic usability evaluation	Metaphor of human-thinking	Task analysis	Cognitive walkthrough	Heuristic evaluation
					x	
						x
						x
						x
				x	x	x
	x	x	x		x	x
x	x				x	x
x						x
						x
x						x
x					x	x
					x	x

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5.1.2.1 Heuristic Evaluation

Heuristic evaluation is one of the most used usability evaluation methods [172]. It involves the participation of usability specialists, who analyse the interactive elements of a system, being guided by an established set of heuristics [173]. Heuristic evaluation involves a small set of evaluators that examine the interface and judge its compliance with recognized interface design and usability principles, i.e., the heuristics [174]. This evaluation method proposes that each expert performing the assessment inspects the user interface to identify usability issues independently; only after all experts have completed their evaluations, should they share their results among them. This restriction is necessary to ensure that the evaluations are independent and impartial from each other [173]. According to Nielsen [160], three to five experts are generally required to carry out the heuristic evaluation. The Nielsen's heuristics were the most commonly reported in the literature (Table 14).

In the context of usability evaluation by experts, heuristics evaluation refers to the inspection of products and services to verify their compliance in terms of usability. However, as previously mentioned, heuristics can also be used as design guidelines: Chapter 4 details generic and specific heuristics for interface design and. From all the heuristics there presented, some were also retrieved during our scoping review. These were heuristics for:

- Gesture interaction [175]–[181];
- Mobile interfaces [33], [85], [182]–[187];
- Websites [188]–[192];
- Interactive television (iTV) [193], [194];
- m-Commerce applications [195];
- Mobile augmented reality [196];
- Security in online Health Social Networks [197];
- Health information system (HIS) [198];
- e-Governance [199];
- Human-robot interaction (HRI) system [200];
- Assistive robotic [201];
- Medical devices [202].

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In addition, there were also retrieved heuristics specific for both type of technology and users: heuristics to evaluate smartphones [86], general mobile based applications [85], and websites targeting older persons [188].

As all of these heuristics have already been described and linked to a comprehensive set of operational principles that can be used both to guide the design of user interfaces as well as to evaluate the usability of the same digital solutions, no further details on the heuristics is given in this section.

Table 14 Generic sets of heuristics reported in the included reviews

	Baharuddin et al. [166]	**Chuan et al.** [79]	**Ellsworth et al.** [167]	**Fernandez et al.** [168]	**Fernandez et al.** [78]	**Fu et al.** [169]	**Hussain et al.** [170]	**Lim et al.** [80]	**Yen & Bakken** [171]
Nielsen's heuristics [16]	x	x	x	x	x	x	x	x	x
Gerhardt-Powals Heuristics [62]				x					

5.1.2.2 Cognitive Walkthrough

Cognitive walkthrough is the simulation of the user's cognitive behaviour by the expert when answering questions regarding their cognitive model [203]. In practice, it assesses whether the order of the tasks in a system reflects the cognitive processes and the way people think anticipating the "next steps". As a group, experts run a step by step process, setting a set of questions at each step browsing all particular solution paths, examining each action while determining if expected user's goals and memory content would lead to choosing a correct option [165]. After identifying the issues/problems that can be improved, experts gather this information in a report, which is further used to inform the redesigning of the digital solution [204].

5.1.2.3 Task Analysis

Task analysis means learning with the goals and habits of users [204] and, therefore, it should define what the user is engaged to do (actions and/or cognitive processes) to accomplish a task. The technique consists of an analysis of what the user should perform in terms of actions and cognitive processes to perform a certain task. A

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detailed task analysis can be accomplished to understand a system and its information flow. Failure to implement this method increases the likelihood of costly problems in the development phase. Once the tasks are defined, the functions required to support them can be specified with precision [204].

5.1.2.4 Metaphor of Human-Thinking

Metaphors of human thinking aim to focus inspection on users' mental activity and to make inspection easily applicable to different devices and use contexts. Building on classical introspective psychology, metaphors of human thinking bases inspection on metaphors of habit formation, the stream of thought, awareness and associations, the relation between utterances and thought, and knowing [205].

5.1.2.5 Systematic Usability Evaluation

Systematic Usability Evaluation (SUE) [206] inspection is a usability evaluation method aiming to supply usability experts with a structured flow of activities, allowing them to obtain more reliable, comparable, and cost-effective evaluation results. This is obtained especially due to the use of evaluation patterns, entitled "Abstract Tasks" (AT), that describe the evaluator's activities to be performed during inspection. AT helps share and transfer evaluation know-how among different evaluators. A further notable advantage provided by the SUE inspection over other existent approaches is that it focuses on navigation and information structures, making evident some problems that other "surface-oriented" approaches might not reveal (Ibid.).

5.1.2.6 Perspective-based Inspection

In perspective-based inspection, experts conduct an oriented and narrow evaluation that can be based on design perspectives, inspectors' tasks, or metric calculation [78]. The perspective-based inspection gives different inspectors different and focused responsibilities, as opposed to the same general responsibility. It also provides an inspection procedure for each perspective, as opposed to just a list of usability issues [207]. The perspective-based usability inspection is focused on one user/persona or task perspective. Evaluators go through the interface with the consideration of each perspective, such as a power user, new user, or elderly user [163].

5.1.2.7 Guideline Review

Guideline review implies experts to verify the consistency and compliance of the interface using a set of standardized recommendations [207] The evaluator compares an interface against the detailed set of recommendations. These can be used for creating an interface (typically used by designers and developers) or evaluating it for compliance (typically performed by usability evaluators) [163]. It is possible to include here automated evaluation methods used to review guidelines compliance such as source code checking used for usability or accessibility evaluation [78] (e.g., [208],[209]).

5.1.3 Instruments to Support Usability Inspection Methods

Inspection methods present difficulties in terms of application, which has led to the growing establishment of instruments to support inspection with heuristics. In practice, these instruments entitled “heuristics checklist” aggregate and conjugate different heuristics for a given digital solution, for example, a checklist of heuristics for mobile phones.

Checklists are a predefined set of verification points to operationalize heuristics, and against which user interface components are compared. The advantages of using checklists include reducing memory load, errors, and workload [210]. The checklists can be used as a practical design support tool, or as an evaluation support tool to suggest necessary areas for interface redesign. They can be used throughout the design process in evaluating multiple design alternatives. [211]. For example, using usability checklists enhances the effectiveness and efficiency of heuristic evaluation [212] and it has been found that using a checklist lead to the identification of 90% of usability problems. These findings contrast with a previous report [213] suggesting that heuristic evaluation (without a checklist) typically does not predict more than 30 to 50% of usability problems. These results suggest that checklist evaluation might improve the traditional heuristic evaluation technique [212]. Although there are more, this scoping review identified three instruments to support inspection methods: the Mobile-specific Heuristic Evaluation checklist [187], the Usability of Web-based Information Systems checklist (based on ISO 9241 and Nielsen’s heuristics) [214] and the MiLE+ (based on 82 technical heuristics - 36 navigational heuristics, 8 content heuristics, 7 technology / performance heuristics and 31 interface design’ heuristics) [215]. In addition to these, other checklists are widely used in the development and evaluation of specific technologies, such as the checklist for mobile phone user interfaces [212] and the accessible smartphone interface design heuristics checklist [211]. Also, there is a checklist specifically for older persons, the Touch-based Mobile Heuristics Evaluation for elderly people [85].

5.1.4 Recommendations to Promote Usability and the Methodological Quality of Studies Assessing Experts Evaluation of Usability

Methodological quality can be defined as “the extent to which study authors conducted their research to the highest possible standards” [216]. However, poor assessment of usability impacts the quality of the technology being assessed [217]. Therefore, having recommendations that inform the design of usability studies can help study authors when designing their usability studies. In this sense, some important aspects should be considered when planning and conducting a usability inspection evaluation,

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especially regarding evaluators, heuristics and task selection, evaluation procedures, and results report.

5.1.4.1 Evaluators

It is highly recommended that multiple evaluators are involved in an inspection evaluation to ensure the highest possible detection rate of usability issues. The recommended number of evaluators varies between three to five since larger numbers do not gain much additional information per extra participant [160]. There are no specific guidelines on the characteristics that specialists should have, however it is suggested that these experts have proven experience in HCI. They should typically be usability experts and preferably with domain expertise in the industry type of the digital solution under development. It is very important to train the evaluators, so they know exactly what they are meant to do and cover during their evaluation. The training session should be standardized to ensure the evaluators receive the same instructions and to avoid bias in their evaluations.

5.1.4.2 Heuristics and Tasks Selection

One of the most important steps in an inspection evaluation is the establishment of an appropriate list of heuristics and the selection of typical tasks that should be considered during the evaluation. Heuristics can help the evaluators focus their attention on certain issues and for that reason, it is important to use generic heuristics to ensure a global assessment of the interface. These can be complemented with specific heuristics that address concrete aspects of that type of digital solutions. In this context, the use of checklists can support the verification of heuristics, since they allow to detail each heuristic in more exhaustive aspects and thus considerably facilitate the evaluation. The use of heuristics checklists also simplifies the analysis and results interpretation, as well as it helps to prioritize the need to solve usability problems. It is also important to select typical tasks that are the ones that are crucial for the fulfilment of the objectives of the system, and consequently, the ones that are most important for the user to be able to perform correctly. After these tasks are assessed, the evaluator can cover others based on their experience and expertise.

5.1.4.3 Evaluation Procedures

Before starting the evaluation, it is important that the evaluator review the product to get a general perspective of its structure and functionalities. Then, in terms of heuristic evaluation, a general recommendation would be that evaluators go through the interface at least twice. The first round of inspection would be intended to get a feel about the flow of the interaction and the general scope of the system. The second inspection then allows the evaluator to focus on specific interface elements while knowing how they fit into the larger whole [23].

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The output from using the heuristic evaluation method is a list of usability problems in the interface with references to those usability principles that were violated by the design in each case. The evaluator must specify the heuristic that is not being met as specific and as detailed as possible, and list each usability problem separately explaining why each particular aspect of the interface element is a usability problem [23]. There are two main reasons to note each problem separately: first, there is a risk of repeating some problematic aspect and second, it may not be possible to fix all usability problems in an interface element or to replace it with a new design - but it could still be possible to fix some of the problems if they are all known.

5.1.4.4 Results Report

The report of the results of the usability inspection evaluation is a key aspect because it will guide the interface redesign. Heuristic evaluation does not provide a systematic way to generate fixes to the usability problems or a way to assess the probable quality of any redesigns. However, because heuristic evaluation aims to report usability problems concerning established usability principles, it will often be relatively easy to generate a revised design according to the guidelines provided by the violated principle for good interactive systems.

Once all evaluators perform their evaluation, data should be put together in a complete list of usability problems and mapped to each heuristic verified. Then evaluators should prioritize potential problems by assigning severity ratings to each item, using, for example, Nielsen's Likert rating scale that ranges from zero ("I don't agree that this is a usability problem at all") to 4 ("Usability catastrophe: imperative to fix before the product can be released"). A traffic-light colour scheme that varies from green (example of best practice) to red (critical problem) to graduate usability issues can also be considered. While identifying usability problems, evaluators are encouraged to suggest potential solutions for these problems based on heuristics. Along with severity, also the frequency with which a problem is identified can be an important issue as it means that it is a barrier for many evaluators. Together severity and frequency assessments inform designers and developers with guidance about the order in which usability problems should be addressed [218].

Usability inspection evaluation is an essential component of the usability evaluation of digital solutions; however, it cannot be considered in isolation or stray from the usability test evaluation that involves real users in the evaluation sessions. Ideally, evaluation with experts should take place before testing with real users, so that the biggest usability problems are discovered and addressed before they prevent participants from discovering harder to spot workflow specific issues. Furthermore, it promotes the combination of methods of different nature, which is considered a good practice in terms of usability evaluation. Even though inspection methods find many usability problems that are not found by users testing, it is also the case that it may miss some problems that can only be found by users. Besides that, evaluators are

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probably likely to overlook usability problems if the system is highly domain-dependent and they have little domain expertise [219].

Eliminating usability errors before usability testing allows the testing to reveal more unique and subtle usability concerns. In this sense, heuristic evaluation is complementary to user testing, since it does not provide any insights on how actual users use the system, which is fundamental for the real adaptation of the technology to the users and the context of use. The next chapter presents a usability evaluation by users and details their procedures and principles.

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6 Usability Assessment Involving Users

The users' evaluation of usability is part of the usability assessment of any digital solution. This evaluation assumes particular relevance for digital solutions targeting older persons due to their specific needs and characteristics, such as lower levels of digital literacy or multiple health conditions, which can dictate their predisposition, motivation and ability to use digital solutions. Furthermore, older persons are a very heterogeneous group including healthy and active individuals as well as individuals with multiple clinical conditions and who are dependent on others, and a diversity of individuals in between these two extreme profiles. Conceivably, they have different needs, preferences, and expectations on what regards digital solutions, requiring that usability evaluations include a wide range of users that are representative of the target users' population. However, the opinion of some subgroups of older persons, such as older persons with mild cognitive impairment is not always reported, despite being fundamental to have more acceptable and useful products and services that are used safely and effectively [97].

This chapter describes the procedures of assessment of usability evaluation by users and details a set of principles and procedures to be considered within the SHAPES project by the partners involved in the implementation and/or evaluation of the SHAPES platform and digital solutions.

The content of this chapter is based on a scoping review of reviews aiming to synthesize current practices of users' evaluation of usability. The data gathered is complemented by relevant information from other sources purposefully selected. This chapter also sets the foundations of the procedures of usability evaluation by users discussed with SHAPES partners.

6.1 *Current Practices on Users' Evaluation of Usability*

6.1.1 Information Sources

This section is based on the findings from a scoping review of reviews on procedures of usability evaluation by users, whose methodology is presented in chapter 1 (Introduction).

A total of 20 reviews both meet the eligibility criteria and contain relevant information concerning current practices on the user's evaluation usability. Table 15 presents the main characteristics of these reviews (authors and year, purpose, and number of included studies in the review).

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Table 15 General characteristics of included reviews

Authors & Year	Purpose of the paper/study	Studies included in the review (N)
Allison et al. [165]	Reviews methodologies and techniques to evaluate websites; provide a framework of the appropriate website attributes that could be applied to any future website evaluations.	69
Azad-Khaneghah et al. [220]	Reviews the rating scales used to evaluate usability and quality of mobile health applications.	87
Baharuddin et al. [166]	Proposes a set of usability dimensions that should be considered for designing and evaluating mobile applications.	Not reported
Bastien [221]	Lists test procedures and defining and developing tools to help conduct user tests.	Not reported (Narrative review)
Bhutkar et al. [222]	Lists the most applied usability evaluation methods and related emerging trends.	30
Cavalcanti et al. [223]	Aims to understand which methods and user assessment approaches are commonly used in motor rehabilitation studies that use Augmented Reality applications.	32
Ellsworth et al. [167]	Revises methods employed for usability testing on electronic health records (EHRs).	120
Fernandez et al. [168]	Analyses which usability evaluation methods have proven to be the most effective in the Web domain.	18
Fernandez et al. [78]	Analyses which usability evaluation methods have been employed to evaluate Web applications over the last 14 years.	206

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Fu et al. [169]	Assesses the usability of diabetes mobile applications developed for adults with type 2 diabetes	7
Hussain et al. [170]	Reviews the relevant and appropriate usability dimensions and measurements for m-banking applications; propose a set of usability dimensions and measurements for m-banking evaluation.	49
Inal et al. [224]	Analyses how usability is being addressed and measured in mobile Health interventions for mental health problems.	42
Klaassen et al. [225]	Analyses if usability methods are equally employed for different end-user groups and applications.	127
Lim et al. [80]	Analyses existing usability metrics, methods, techniques, and areas in mobile augmented reality learning.	72
Narasimha et al. [226]	Analyses the characteristics of usability-related studies conducted using geriatric participants and the subsequent usability challenges identified.	16
Shah & Chiew [227]	Identifies, analyses, and synthesizes the usability features and assessment approaches of pain management mobile applications targeted at the evaluation studies.	27
Simor et al. [228]	Reviews usability evaluation methods used for gesture-based games, considering devices with motion-sensing capability.	10
Sousa & Dunn Lopez [229]	Identifies psychometrically tested questionnaires that measure usability of e-health tools.	35
Yen & Bakken [171]	Reviews and categorize health information technology usability study methods and to provide practical guidance on health IT usability evaluation.	346

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Zapata et al. [230]	Reviews a set of selected papers that perform a usability evaluation of mHealth-related mobile applications.	22

An analysis of the procedures of usability evaluation with users reported in each of the 20 included reviews was performed. This was guided by the framework of Ellsworth et al. [167] for reporting usability evaluations. The following operational definitions were used:

- Study evaluators, i.e., the individuals who conducted the usability evaluation;
- Participants, i.e., the individuals who were asked to evaluate the usability of a product or service;
- Tasks, i.e., the activities that participants were asked to perform when evaluating the usability of a product or service;
- Methods and techniques - methods refer to the set of techniques used to perform formative usability evaluation (i.e., usability evaluation or testing to improve usability) at any stage of the product or service development. Usability evaluation techniques refer to a set of procedures used to perform a usability evaluation and collect data of a certain type. The usability assessment usually requires the combination of more than one method and/or technique, can be conducted remotely (i.e., evaluators are separated in space from users) or in the presence of the participants, and can be synchronous (i.e., occur at the time of the participants' interaction with the system) or asynchronous;
- Test environment, i.e., the environment where the evaluation of usability takes place: (i) laboratory or controlled conditions, usually a transversal assessment or (ii) in a real context, i.e., the usability assessment is carried out in the same context and circumstances where the end product is expected to be used, which is usually a longitudinal assessment.

Details on the characteristics of each of these components were extracted from the reviews above and are presented in the following section.

6.1.2 Synthesis of Current Procedures and Practices for Users' Evaluation of Usability

A detailed analysis of included reviews revealed a lack of standardized procedures and widely accepted good practices. The results are described in terms of characteristics of study evaluators, participants and tasks reported; methods and techniques reported, common combinations of instruments used, and type of environment where the usability evaluation took place.

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6.1.2.1 Study evaluators

The characteristics of the study evaluators were seldom reported. The only reports were on blinding of the study evaluator, and on the common use of graduate students as participants in users' evaluations.

6.1.2.2 Participants

The characteristics of participants reported were: mean age or age range, gender, whether they were healthy participants or individuals with a specific clinical condition, health care professionals or family or informal caregivers, and whether participants had previous experience with the product or service being assessed. The sample size was generally reported, although seldom justified.

6.1.2.3 Tasks

Tasks vary in line with the aims, target population, interfaces, and details of the usability evaluation study and of the product or service; the reporting included the number of tasks performed and the duration of tasks. These were usually typical tasks that reflect the system's intended use.

6.1.2.4 Methods and techniques

Table 16 lists the techniques used for usability evaluation by users within the method of test. A method of test involves observing users while they perform predefined tasks and consists of collecting mostly quantitative data; the test is centred on what the user does, and not so much on what the user says.

Table 16 Techniques used for usability evaluation by users within the method of test

Technique	Definition and examples
Performance evaluation	Evaluated by recording elements related to the execution of a task. Examples include: • Execution time, • Success/failure, • Number of errors, • Percentage of users that completed a task, • Eye-tracking,

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	• Automated usability evaluation / Analytics / Log files / Web Usage Analysis / App-use generated data / Sensor data / Heat Maps).
Observation	Attentive visualization and systematic recording of a phenomenon, including people, artefacts, environments, behaviours, and interactions. Observation can be direct, when the researcher is present during the task execution, or indirect when the task is observed through other means, such as video recording.
Think Aloud	The users are invited to talk about what they see, do, think, or feel as they interact with the system or service.

Table 17 lists the techniques of the method of inquiry. These techniques provide valuable, subjective, and usually qualitative information on the users' opinions and expectations.

Table 17 Techniques of the method of inquiry

Technique	Definition and examples
Focus Groups	Involves a small number (up to 10) of people in an informal discussion.
Interviews	Involves a one-to-one interaction to gather opinions, attitudes, perceptions, and experiences.
Scales/Questionnaires	Collects data on characteristics, thoughts, feelings, perceptions, behaviours, or attitudes, measuring either one (scale) or several (questionnaire) dimensions of usability. It is important to mention if instruments being used are validated.
Diaries	It is a field technique in which the users and evaluators are in different locations and data are recorded when an event occurs (e.g., it can be requested by the study evaluator or can be a spontaneous description of an event), usually in the context of daily activity.
Card Sorting	Helps design teams to build or improve user interface, information flow, or the overall user experience. It involves participants using logic while sorting content or "cards" into categories or groups that make sense to them, given the information they are provided with.

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Among the methods of inquiry, questionnaires/scales and interviews were the most often referred. Among the first ones, the most commonly mentioned were the System Usability Scale (SUS) and the Post-Study System Usability Questionnaire (PSSUQ). An important aspect to guarantee is that valid and reliable scales and questionnaires are used. Other questionnaires reported in the reviews, include:

- Questionnaire for User Interaction Satisfaction (QUIS).
- Software Usability Measurement Inventory (SUMI).
- Usefulness, Satisfaction, and Ease of use Questionnaire (USE Questionnaire).
- Computer System Usability Questionnaire (CSUQ).
- After-Scenario Questionnaire (ASQ).
- Perceived Useful and Ease of Use (PUEU).
- IsoMetrics usability inventory (ISOMETRIC).
- Health Information Technology Usability Evaluation Scale (Health-ITUES)
- User Mobile Application Rating Scale (uMARS).
- IBM ease-of-use.
- ISO 9241-11 Questionnaire.
- Single Ease Question (SEQ).
- Ad-hoc Questionnaires developed by study authors (no data on validity or reliability provided).

Techniques from different methods are usually combined when conducting a usability evaluation by users and commonly reported combinations are:

- Observation + Scale/Questionnaire + Performance Evaluation + Think-Aloud.
- Observation + Scale/Questionnaire+ Interview + Diary studies.
- Scale/Questionnaire + Performance Evaluation + Think Aloud + Interview.
- Observation + Performance Evaluation + Think Aloud + Interview.
- Performance Evaluation + Scale/Questionnaire + Interview.
- Performance Evaluation + Scale/Questionnaire + Focus Group.
- Performance Evaluation + Scale/Questionnaire + Observation.

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- Observation + Scale/Questionnaire + Interview.
- Observation + Scale/Questionnaire.
- Observation + Interview.
- Think Aloud + Scale/Questionnaire + Interview.
- Think Aloud + Scale/Questionnaire + Interview.

The combination of techniques from different methods is a good practice. Different methods and techniques have different strengths and limitations [228], and therefore its combination is more likely to provide a comprehensive view of usability problems [231]. For example, scales and questionnaires are easy to use and useful for gathering self-reported data about the user's perception but might have limited value informing on which aspects of the system need to be targeted for improvement [167]. Interviews and observation are recommended when the number of participants is small because both generate high amounts of data that is time-consuming to obtain and analyse. Nevertheless, interviews can be particularly useful to understand the reasoning of the user when facing a problem, and observation provides an insight into the moment when a problem occurs [228]. It is argued that think-aloud protocols may result in the loss of focus on the tasks being performed, while user performance reporting is an easy assessment, particularly in those cases where the system automatically records the performance indicators, but may provide limited information if used alone (Ibid.).

6.1.2.5 Test environment

The environment where the usability assessment takes place was not always characterized [222], but test environments include hospitals or specific units within the hospitals (e.g., Intensive Care Units) and laboratories (Ibid.), and the everyday environment of the intended users or their representatives [224]. The test environment depended on the stage of technology and aims.

Overall, there seems to be a lack of standardization and consensus on the more appropriate procedures to perform users' evaluation of usability. This lack of consensus led us to propose a set of principles and guidance, discussed with the partners of the SHAPES project in an attempt to reach a common understanding on the procedures of users' evaluation of usability that should be followed to assess the usability of SHAPES platform and digital solutions.

6.1.3 Remote Usability Evaluation by End-Users

Remote testing was hardly mentioned in the reviews included in our scoping review. However, and considering the limitations imposed by the actual situation due to Covid-19, it was decided to have a sub-section dedicated to remote testing. Remote usability

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testing differs from traditional usability testing in one aspect that is the fact that the study evaluator and the participant are in different physical spaces. The remote sessions can be synchronous or asynchronous. In synchronous testing, study evaluators and participants share the same “virtual” space and the study evaluator can watch the usability test and guide the assessment by interacting directly with the participant. In an asynchronous remote session, there is no interaction between the study evaluator and the participant, who completes the usability evaluation on their own and may record the session for later review by the study evaluator [232], [233].

The remote testing of usability requires video conferencing applications or remote applications sharing tools that allow sharing computer screens. Numerous tools are available that could facilitate remote testing, such as Microsoft NetMeeting, WebEx, WebQuilt, and IBM Lotus [234].

User Diaries can also be an effective tool to conduct remote usability tests. There are several Diary Apps (e.g., In-The-Moment, Mobile Diary Study App) that enable users to save or record real-time behaviours (photos, screen recording or personal notes) when using a digital solution.

User Analytics and Feedback apps are other interesting supports to ensure remote access to user data. Solutions like Hotjar, OpinionLab, UserVoice or Intercom allow not only the collecting of users’ opinions, but also heatmaps, remote screen recordings, feedback polls, surveys, among other features. In some cases, digital solutions can trigger in-app questions about features in the exact moment they are being used, allowing accurate perception of usability (e.g., Instabug) [235].

The evidence suggests that synchronous testing should be preferred over asynchronous testing. The reliability (i.e., consistency) and sensitivity, i.e., the ability to identify usability problems [236] of asynchronous testing have been questioned as it has also been its ability to identify the subjective usability elements, such as user preferences, misconceptions, values, or motivations. These are better explored through synchronous remote testing [237], [238].

Additional challenges may raise from synchronous remote evaluations that need careful consideration during the planning phase. For example, participants are evaluating a technology that they are not familiar with using a usability testing procedure that is likely to be also unfamiliar. This can add further cognitive burden for the participants [238]. Furthermore, the study evaluator may face supplementary challenges in creating and maintaining an appropriate communication strategy (Ibid.) that is fundamental to some usability evaluation techniques. Therefore, it is suggested that when using remote usability testing, careful consideration is placed on the general recommendations for usability testing, plus those that might be specific of remote testing. These include verification in advance of whether the product or service being tested is accessible to users, that participants can download/access the screen-

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sharing software [232], [233], and that the study evaluator has previous experience conducting these type of assessments (consider a mock test).

6.2 Recommendations to Promote the Methodological Quality of Studies Related to Users' Assessment of Usability

The American Medical Informatics Association (AMIA) developed 10 recommendations aiming to promote the usability of electronic health record (EHR) systems to enhance patient and quality of care safety [217]. The AMIA recommendations cover four areas: (i) human factors health information technology (IT) research; (ii) health IT policy; (iii) industry recommendations; and (iv) recommendations for the clinician end-user of electronic health record software. Further specifications were made within each of these areas.

Despite being specific for EHR, the AMIA recommendations are relevant for any digital solution and, therefore, for SHAPES digital solutions, particularly those related to human factors health information technology. These are: (i) prioritizing of standardized use cases, including patient selection (correct patient), clinical documentation (correct record, appropriate documentation quality), management, results review (correct data and appropriate view), and advance directive documentation (correct status); (ii) develop a core set of measures for adverse events related to health IT use; and (iii) research and promote best practices for safe implementation of technology. It is also critical that best practices are assessed and defined for the safe implementation and ongoing effective use, including training requirements, assessment of application configuration(s), technology (hardware/software) infrastructure and support, systems integration, workflow process(es), organizational culture and policies, and externalities that may confound the safe and effective use of the digital solution.

A scale has been developed to assess the methodological quality of studies assessing usability. It may also be used to inform the design of usability studies (Silva et al., 2019). The following adaptations were made to this scale to guide the design of users' evaluation usability studies:

- Define a protocol showing coherence between the procedures used to assess usability (e.g., instruments, context) and study aims.
- Use valid measurement instruments of usability (i.e., check if there is evidence that the instruments used assess usability).
- Use reliable measurement instruments of usability (i.e., check if there is evidence that the instruments used have similar results in repeated measures in similar circumstances).

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- Use procedures of assessment for usability that are adequate to the development stage of the product/service.
- Use procedures of assessment for usability that are adequate to study participants' characteristics (for example, instruments that are suitable for healthy older persons may not be appropriate for older persons with cognitive impairment).
- Employ triangulation of methods for the assessment of usability.
- Perform the analysis in line with the study's aims and use a method of data analysis that is appropriate considering the scale of measurement.
- Use participants that are representative of the potential user's population.
- Assure that the tasks that serve as the base for the usability assessment are representative of the functionalities of the product/service.
- Use study evaluators that are experienced or have been adequately trained.
- Use a study evaluator that is external to the process of product or service development.
- Use an adequate number of participants and provide a rationale for the sample size.
- When appropriate, conduct usability evaluations in the real context or as close as possible to the real context where product/service is going to be used.
- When possible and appropriate, perform a usability assessment based on continuous and prolonged use of the product/service over time.

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6.3 General Principles and Guidance for Usability Assessment by Users

Based on existing guidelines and the review of the literature we propose a set of principles/procedures for usability evaluation with users within the SHAPES project. These are detailed below by the study phase: planning and preparation of the usability evaluation with users' study, conducting and reporting (Table 18).

Table 18 A proposed guide of procedures for usability evaluation with users for each phase of the usability study: planning, conducting, and reporting

	Planning	Conducting	Reporting
Study evaluator	• Sample size – provide a rationale • Experience with usability evaluation with users (if none, plan training) • Establish clear inclusion and exclusion criteria (age, gender, educational level, academic background) • Clarify the roles on the research (evaluator, observer) and define responsibilities	• Evaluator – Interacts with the participant and guide the session • Observer – Is responsible for collecting data on the interaction	• Present sample size and rationale • Summarise characteristics (age, gender, educational level, academic background) • State whether external to service or product development team • State the level of experience using the technique of usability evaluation and the technology (if no previous experience. Give details on training procedures)

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Participants	• Sample size – provide a rationale • Define clear inclusion and exclusion criteria (rationale for recruitment and profile definition) • Define sampling methods (Probability / Non-probability) and place of recruitment	• Complete the tasks, following the indications of the evaluator.	• Present sample size and rationale • Present sample selection (method and place of recruitment) • Summarise characteristics (age, gender, educational level, digital literacy, previous experience using the product or service being evaluated) • Present clinical conditions (if relevant for the study): asymptomatic or with a specific clinical condition or from a specific group (occupational group, severity of the clinical condition, disabilities) • Present motivations and expectations
Methods and techniques	• Provide a rationale for the combination of methods and techniques	• Conduct in line with the guidelines of best practice.	• Present the rational and full description of methods and techniques

	• Define equipment needed • Select valid and reliable scales/questionnaires		• Provide validity and reliability indicators
Task	• Define the number • Provide a detailed description of tasks • Develop a participant script	• Set up the room • Orient the participant • Collect data (including critical incident registration)	• Indicate the number of tasks completed, time/duration (mean, minimum, maximum), success rate and error analysis
Test environment/ equipment	• Define best possible options: lab test or field test or both; remote test or face to face • Determine facilities (space layout and material) and distribution on space of the research team members (evaluator, observers) • Ensure the existence of observation room and recording room • Ensure the proper functioning of all equipment necessary for the	• Make sure everything is as detailed in the plan	• Describe compliance of test environment requirements • Test environment limitations • List any deviation from the test environment planed • Report critical incidents

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	test evaluation (computer, smartphone, television)		

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6.4 Practical Recommendations to facilitate Usability Assessment by Older Persons

In this section, the particularities and factors that may hinder the usability assessment of digital solutions involving older persons are addressed. Also, practical recommendations are provided to facilitate the users' evaluation of usability while attempting to increase the sensitivity of the evaluation process.

Four major aging-related barriers to usability are identified in the literature, including: (i) cognition, (ii) physical abilities, (iii) perception and (iv) motivation [82], [239]–[242]. Cognitive barriers include a decline in working memory, difficulties in concentrating, or understanding instructions. Examples of physical barriers are poor fine motor control and dexterity decreased velocity of movements or decreased range of movement. Perception barriers include visual and hearing impairment and decreased tactile acuity. Lack of trust in one's own ability to use technology or being afraid of damaging the technology are examples of motivational barriers [242]. These barriers modulate the ability of the individual to interact with the technology and should be considered when designing the technology (Ibid.), but also when assessing its usability. Failure to take these aspects into account may result in greater odds of missing usability problems and resulting in a product or service that is difficult to understand and learn, inefficient to use, inducive of user errors, and frustrating to the user (Ibid.).

Therefore, there are general recommendations to be considered. For example, in order to make the information clearer when providing written information to the older person there are several recommendations (e.g., [243], [244]). Some of them to be considered include:

- Duplicating information (e.g., both verbal and written);
- Giving a written script to the participant;
- Using simple, direct and short sentences;
- Using font size 14;
- Using sans-serif fonts (e.g., Arial or similar font);
- Avoiding words in capitals and italics;
- Using 1.5 line spacing;
- Ensure text and background have sufficient colour contrast (preferably black on white);
- Not using shadows, outlines, strikethroughs, gradients or colours on text;

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- Using bullet points and sub-headings to break up text and organise information;
- Giving numbers in the form of figures instead of letters;
- Not using abbreviations;
- Providing easy-to-read documents and ensuring digital accessibility (accessible PDFs and word documents);
- Making documents in distinct accessible formats, such as braille format.

Communication is also a key element in the evaluation of usability by users. A set of general recommendations is compiled to help establishing an appropriate communication with the older person:

- Ensure informed consent procedures. If older persons are unable to provide consent, ensure procedures for obtaining approval from the legal representative. Also, ensure fully informed understanding of the implications of the older person's participation in the tasks (Cf. 7.6 and Appendix);
- Avoid making ageist and ableist assumptions about older technology users and their digital literacy/competencies;
- Address him/her by the name, using the title he/she prefers (e.g., Mr, Ms, Mr,) and avoid endearing or diminutive terms, simplified vocabulary, and exaggerated intonation that conjointly configures "elderspeak";
- When in need of a sign language interpreter, always address the person being interpreted, avoiding exaggerated gestures;
- Start with friendly questions not directly related to the technology use, i.e., take a few moments to establish rapport and confidence;
- Use common language and practical examples of daily life, avoid technical jargon and abstract concepts, and ask if clarification is needed when providing instructions;
- Do not rush through questions and speak slowly giving the user time to process what is being asked or said – time spent discussing concerns allows gathering important information on the user experience;
- Use active listening skills (e.g., maintain eye contact, general short incentives – "I see…", "Hmm, hmm") that help to keep the focus on the assessment;

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- Allow time for feedback and questions, and constantly check that the information is clear and being understood;
- Give the older person enough time to provide answers and to express his/her thoughts on the technology being assessed – allowing time to express concerns enables the user to be more open and comprehensive;
- Probe by asking “Is there anything else you would like to add to what we have discussed?”;
- Ensure that barriers possibly faced by persons with disabilities, including (but not limited to) persons with hearing and/or vision impairments and persons with psychosocial and/or intellectual disabilities are overcome.

When communicating with persons with visual and/or hearing impairments:

- Ensure that the participant can understand the information and communicate properly;
- When in need, ensure sign language interpretation;
- Avoid assumptions regarding the disability of the participant and always consult the specific and individual needs and accessibility requirements of the participant;
- Ensure availability of face-to-face interpretation (including, but not limited to: sign-language, clear-speech, tactile/haptic communication) according to the needs of the individual, and/or remote interpretation through assistive technology (including but not limited to: smart-phones, tablets microphone systems etc.) if and when appropriate;
- Talk slowly and clearly in a normal tone, avoiding using high-pitched voice or over exaggerated gestures;
- Face the older person directly, i.e., in a way that he/she can lip-read or pick up visual clues if useful;
- Be aware of background noises that can mask what is being said – try to minimize them as much as possible;
- Avoid interruptions and multiple simultaneous conversations;
- Keep a notepad handy so your information can be written whenever needed;
- If appropriate, use visual aids interactively during the assessment to help clarify and reinforce comprehension of key aspects;

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- Consider having duplicated information (i.e., written and verbal) beforehand;
- Make sure the participant knows when you are changing the subject being discussed (e.g., pausing briefly, speaking more loudly, gesturing towards what is being discussed);
- Ensure the room has an adequate light (not too dark, not too bright);
- Ensure a position that allows natural eye contact (e.g., face to face and not behind the interviewee) while ensuring a strategic position. For example, the interviewee could be in a position that avoids having the window in front of him or her to avoid glare from the sun.
- Ensure throughout the whole process that information is being understood.

In cases of blind or visually impaired persons:

- Check if the older person has or needs any devices to facilitate communication;
- Make sure there is adequate lighting, particularly in the assessor's face;
- Avoid operating with a distracting background;
- Consider alternatives to traditional reading, such as recorded instructions, braille formats;
- When using printed materials, assure they are available in accessible formats (e.g., have adequate and easy to read font size, present good colour contrast).

When there is a need to involve family, personal assistants, support persons, etc:

- Include them only by permission, i.e., ask the older person his/her preferences are in regard to companions;
- Primarily address the older person, and address companions only when essential;
- Be aware of communication issues that arise from a three-party interaction (e.g., if the proxy seems to talk over the older adult, direct the conversation back to him/her and use inclusive terms such as "we" or "you" to maintain a sense of joint voices);

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- Consider asking the companion to step out of the assessment place when raising sensitive issues so that the older person’s privacy can be protected/assured.

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7 User Interface Design and Usability Assessment of SHAPES Platform and Digital Solutions

The development and design of a digital solution begins with a deep understanding of who the user is, what his/her needs are and the context where the digital solution is going to be used. It evolves in a dynamic cycle of, developing the product and assessing it until no further changes are deemed necessary and a fully functioning digital solution that works in the real context of use exists. It is an interactive and user-centred process that involves the user from the very beginning. This is essential to develop a digital solution more likely to be of use and value to the user.

In the previous sections we presented guidelines and recommendations for the user interface design and for the usability assessment of both experts (inspection methods) and users. Despite devoting a separated section to each one of these subjects for easiness and clarity of presentation, they are interdependent. In this section, we summarise the main findings from the previous sections and their application to the SHAPES platform and digital solutions and highlight the interconnection between this and previous work within the SHAPES project.

7.1 SHAPES UX Design Guide

The SHAPES Heuristics proposed in section 4.2.4 constituted the basis for the definition and discussion with SHAPES' partners to define the SHAPES user interface design recommendations presented in section 4.4 (Table 10). Based on those findings, this section summarises specific tips to develop user interface components [245] that technological partners can use when proceeding with the development of the SHAPES platform and respective digital solutions. Numbers in between parenthesis refer to the respective numbered recommendation in Table 10.

7.1.1 Visual Components

7.1.1.1 Colour

Among other aspects, this component addresses aspects related to primary colour palette, secondary colour palette, and contrast between the background colour and the colour elements. When developing this component, among others, the following recommendations should be considered: (112) the system should have a good contrast between the background colour and the coloured elements, ensuring readability and perceptibility (e.g., coloured text on coloured backgrounds should be avoided). Avoid pure white background screens or rapid changes in brightness between screens or contrast backgrounds. The system'

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content should not all be in colour alone (colour here is denoted by all colours other than black and white). In particular, the system should give preference to pastel tones over bright tones, avoiding blue and green tones. Avoid using blue, green and yellow in close proximity [44], [83], [84], [86], [88], [92], [100]; and (117) the system should use colours in a conservatively way, limiting the maximum number of colours in use to four [83], [84], [86].

7.1.1.2 Typography

Among others, this component addresses aspects related to type of font, font size, letter spacing, line spacing. When developing this component, among others, the following recommendations should be considered: (39) the system should adopt colour standards, typography, positioning, page titles, among others, in order to facilitate the user's navigation in the interface [86], [91]; and (119) the system should use San Serif type font, for instance, Helvetica, Arial of 12-14px, avoiding fancy font types [83], [86].

7.1.1.3 Scale

Among other aspects, this component addresses aspects related to the distance between objects, maximum and minimum logo size, and maximum and minimum distance of objects to the logo. When developing this component, among others, the following recommendations should be considered: (63) in feet interaction using the whole of the foot sole makes it easier to hit targets; leave enough space between targets as to prevent accidental activation [101, p. 397]. Increasing distance of targets within reasonable limits increases interaction time, but does not increase error [112, p. 271]. Larger buttons and interaction points are needed, once the users use the entire surface of their foot and fine-level control with one's feet is much more challenging [113, p. 10]; and (81) The system should ensure that buttons and icons enlarge when the rest of the text size is increased, and that there is enough space between buttons to prevent hitting multiple or incorrect buttons [85, p. 416-418].

7.1.1.4 Size

Among others, this component addresses aspects related to the size of the pages/screen elements. When developing this component, among others, the following recommendations should be considered: (44) since smartphones have a limited width, the system should be designed in a way that (i) the users will not have to scroll horizontal, (ii) the buttons are visually differentiated from other actionable element, (iii) the elements related to functionality and content understandability are positioned above the scroll line to minimize missing information, allowing users to clearly identify when screens extend beyond the scroll line, and (iv) that the user interface elements are not smaller than the

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smallest average finger pad (1cm - 0.4" - in diameter or a 1cm x 1cm square) [64], [96], [98], [99], [112], [113]. In robotics (51), the system graphical user interface (GUI) and button elements should be sufficiently big in size so they can be easily seen and used (> finger size (~20mm) in case of touch screen, buttons). GUI and button elements should have both easy to understand and big enough graphical and textual information about their meaning [110, p. 402].

7.1.1.5 Copy and Microcopy (Terminology)

Among other aspects, this component addresses aspects related to text structure, spelling and grammar, terms used, and topics related. When developing this component, among others, the following recommendations should be considered: (40) the system should present dynamic content carefully: (i) using an active voice, from short and direct phrases, appropriate grammar and ensuring that abbreviations and acronyms are spelled out the first time they are mentioned on each page; (ii) avoiding attempts at humour, metaphors, vague and ambiguous terms, first-person phrases, violent, negative or degrading terms, psychologically threatening terms (for example, "illegal", "invalid" and "abort"); (iii) and careful choosing the words used in labels, menus titles, menu options, icons and data fields, avoiding the term "hit", using "press" or "click" instead [44], [88], [100], [101]; and (41) the system should provide the date of creation of the content, together with the date of update for each page, and the date of any technical maintenance [88] and screen readers should be able to reach and read all text inserted in the interface.

7.1.1.6 Graphics

Among others, this component addresses aspects related to images, illustrations, and graphics adequacy and accommodation to all users. When developing this component, among others, the following recommendations should be considered: (68) the system should use alternative text (ALT text), as well as explain images and graphics [83], [84], [88], [100], [114]; and (197) the system should use visual elements (colour, typography, layout, images, graphics, personified icons) to trigger the user’s emotions [138].

7.1.1.7 Dynamic Contents

Among other aspects, this component addresses aspects related to videos, objects, and pages/screens transition. When developing this component, among others, the following recommendations should be considered: (30) the system should offer different user control options for the interface, (i) in order to avoid the occurrence of errors by the user or the system itself; (ii) provide clearly marked "emergency exits" when users choose system functions by mistake; (iii) support undo and redo operations and offer the ability to go back or forward; (iv) and

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offering the ability to pause, resume, restart, or end activities [15], [44], [85], [91], [92], [95], [103]; and (83) the system should avoid the use of animation and fast-moving objects, only providing graphics that are relevant [83], [84], [86].

7.1.2 Information Architecture Components

7.1.2.1 Layout

Among others, this component addresses aspects related to the organization of contents and objects on the screen. When developing this component, among others, the following recommendations should be considered: (12) for feet-based interaction, on-screen interfaces should provide a direct spatial representation of the movement of the feet; and (59) the system' graphical interface design and the organization should help prevent errors. Errors and unclear situations for the user should be avoided by guiding the user to select from meaningful alternatives [85], [104].

7.1.2.2 Navigation

Among other aspects, this component addresses aspects related to the content and elements organization and its availability, so the users can easily move through pages/screens. When developing this component, among others, the following recommendations should be considered: (7) the system should provide extra and bolder navigation cues, as well as location of the current screen [83]; and (89) the system' navigation options should allow customization of default font size (preferable on page controls), the magnification of the entire screen, and the magnification lens view under user's finger [96], [98], [99], [112], [113], [120].

7.1.2.3 Search

Among others, this component addresses aspects related to content search, namely how and where to search. When developing this component, among others, the following recommendations should be considered: (62) the system' search engines should cater for spelling errors [83, p. 131]; and (166) The system should predict structured content to enhance navigation and editing, providing content text-search [127].

7.1.3 Interaction Components

7.1.3.1 Input Controls

Among other aspects, this component addresses aspects related to buttons, text fields, checkboxes, and other actionable elements, namely position, size, and its surrounding space. When developing this component, among others, the following recommendations should be considered: (43) the system should include

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buttons and other actionable elements that should be at least 9mm high by 9mm wide, ensuring that buttons are large enough to easily see the image or text on them [64], [83], [85], [96], [98], [99], [112], [113]; and (174) the system should include buttons and other actionable elements that should be surrounded by a reasonable inactive space. If the items are too close, the user will not be able to choose a single one [96], [98], [99], [112], [113], [120].

7.1.3.2 Navigational Components

Among others, this component addresses aspects related to an easy navigation through pages/screens, namely through breadcrumbs, sliders, search fields, pagination, tags and icons availability. When developing this component, among others, the following recommendations should be considered: (67) the system should consider forms in relation to screen readers and offer transcriptions for audio resources, such as subtitles for video. Label the fields and describe the screen readers using tags [100]; and (108) the information should be organized and presented in the system according to its importance, ideally with an index, navigation icons, navigation trails and site map, favouring an ideal navigation experience [44], [88], [101].

7.1.3.3 Informational Components

Among others, this component addresses aspects related to labels, notifications, message box, and icons. When developing this component, among others, the following recommendations should be considered: (5) the system should provide human-computer dialogue, predicting labels associated with screens, texts and objects, preserving the natural cognitive relationship between the user and the system and an easier task accomplishment [85], [87], [103]; and (124) the system should provide clear feedback and when presenting error messages they should be simple, easy to follow, positive and expressed in simple language, so that the user can understand it [15], [44], [83], [86], [92], [95].

7.1.3.4 Containers

Among other aspects, this component addresses aspects related to interface elements used to group other elements, such as the screen menu, namely its size, position, and format. When developing this component, among others, the following recommendations should be considered: (46) the system's main menu should be easily locatable and identifiable. Standard design conventions would likely lead most users to look for a menu on the top, left-hand side of the screen. A collapsed menu is often associated with the three-bar "hamburger" icon that the users are expected to be familiar with. The system should display marked hamburger menus, so that screen readers can identify them, instead of pull down

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menus [64], [83], [96]–[99], [113], [114]; and (69) the system should group related objects and functions by user task or work activity [44], [85], [101].

These components and recommendations should be considered by the partners to build the Design guides of the SHAPES Platform and of each SHAPES digital solution. Given the specificity of the SHAPES digital solutions (e.g., robotics, voice interaction), for each one, technological partners should consult Table 10 on section 4.4.

7.2 SHAPES Usability Inspection Methods

Chapter 5 synthetises current procedures and practices for usability inspection methods, the characteristics of the evaluators involved in the usability inspection, the current usability inspection methods, the instruments used to support the usability inspection as well as the heuristics and tasks used in that assessment. Here, we systematise the information that should be considered when planning and reporting usability inspection methods procedures. During the planning phase, please consider to:

- Use multiple experts.
- Define the rationale for the number and characteristics of experts (e.g., age, gender, academic background, previous experience conducting usability inspection) involved in the usability inspection.
- Triangulate methods of inspection.
- Chose a combination of inspection methods that have a complementary perspective and provide a rationale for your choices.
- Define the rationale for your choice of instruments and check who developed them and how they were developed to guarantee that you use instruments of proven quality.
- Justify your choices based on technology and intended users.
- Define a detailed evaluator procedure script.
- Detail the heuristics used.
- Detail the number and type of tasks used.

When reporting the results of your inspection, please consider to:

- Provide a clear rationale for the number and characteristics of experts involved in the usability inspection and provide information on who the

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experts were (age, gender, academic background, previous experience conducting usability inspection).

- Provide a rationale for the methods used, considering how they complement each other, the type of digital solution or the stage of development or other appropriate justification;
- Describe the instruments used in terms of how they were developed and their psychometric properties (if available);
- Describe the heuristics;
- Provide a clear description of the script and tasks used for the inspection assessment.

After the usability inspection (and also at the end of the usability assessment by users) there will be a number of results and several issues or problems are likely to have been identified. These problems are of different frequency and/or severity. Some problems might have been identified by a large number of participants, while others might have been identified by a minority of participants. Some problems are likely to impact a larger number of participants and hinder the functioning of the product or service, while other problems are likely to affect only a small number of participants or to be related to how the product or service looks, but not affect its functioning. Severity assessments inform designers and developers with guidance about the order in which problems should be addressed [218].

There are different scales to assess the severity of the problems identified in the usability assessment. Nielsen & Loranger [190] have proposed a Severity Rating for Usability Problems as: low, medium, serious, or critical, which is commonly referred in the literature [218], [246], [247] . To classify a problem in one of these categories, Hattink et al. (2016) used an approach where the severity was scored on each of 3 questions with yes (=one point) or no (=0 points):

a. Frequency: Do a substantial number of users encounter the problem?
b. Impact: Does the problem cause much trouble to those users who encounter it?
c. Persistence: Does the problem cause trouble repeatedly?

Critical errors (score 3) are errors that disrupt the product or service usage enough to prevent actual usage. Serious errors (score 2) disrupt the use and can be frustrating enough to stop users using the site or force them to find workarounds for problems. Medium (score 1) and low (score 0) errors can be bothersome to most users but are unlikely to influence the product or system

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usage [247]. However, using Nielsen & Loranger's [190] Severity Rating for Usability Problems does not account for the potential effects on outcome, i.e., an error might not occur frequently but when it does it can have an important impact on the outcome. This is particularly relevant in the field of health, where an error might compromise patients' safety [246]. Khajouei et al. [246] proposed an augmented classification scheme that allows the disclosure of the underlying essence of problem causes, the severity rating, and the classification of the impact of usability problems on the task outcome.

After careful analysis of the problems, the team of designers and developers has to decide which problems were solved and which were not. Therefore, each problem can be assigned a status: (1) Solved, the problem was fixed. (2) Reduced, the problem was partly, but not fully, fixed. (3) Unaddressed, the problem was either deferred or rejected [218]. Figure 1 shows the flow of steps from usability evaluation, to problem rating and prioritizing and then reporting on whether problems were addressed and reasons for not addressing them.

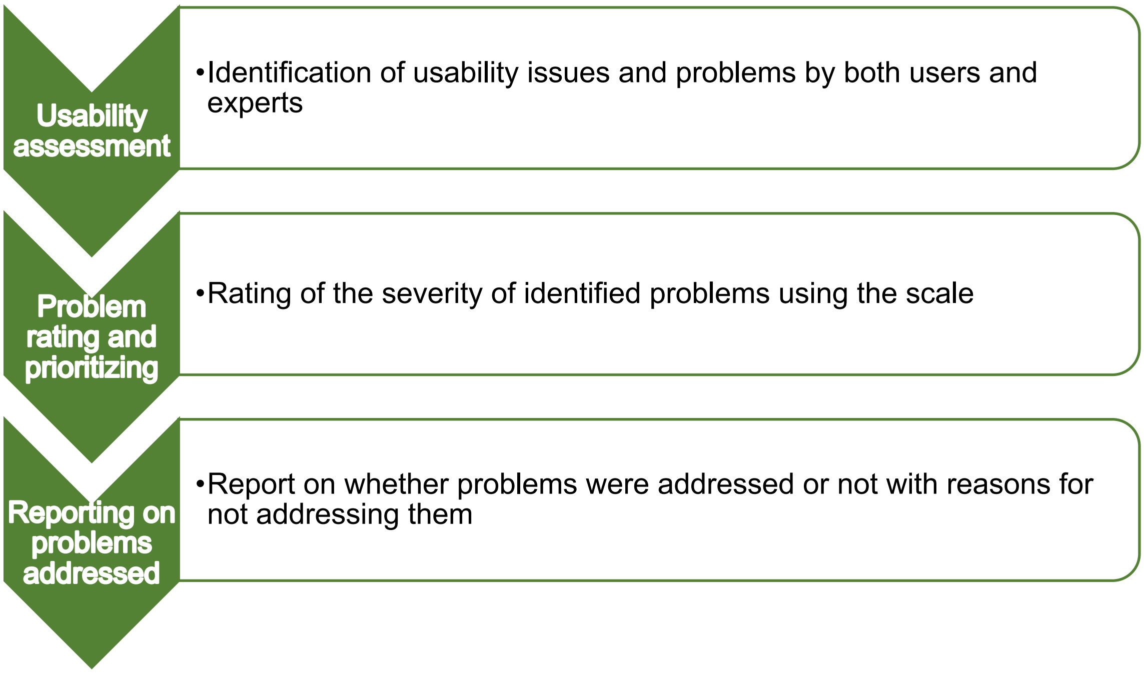

Figure 1 From usability evaluation, to problem rating and prioritizing and reporting

7.3 SHAPES Personas and Usability Evaluation Involving Users

Chapter 6 synthetizes current practices on usability assessment involving users encompassing the characteristics of the participants, the tasks, the methods and techniques used to perform the formative usability evaluation, and the test environment where the evaluation of usability takes place. In terms of what should be considered for these aspects of the usability assessment when planning, consider to:

- Define the criteria that the person conducting the usability evaluation has to meet (age, gender, previous experience, appropriate communication skills) and, if needed, dedicate time to train the person; training should encompass not only the technical aspects of usability assessment, but also communication skills.
- Collect data on the evaluator' age, gender, educational level, background and previous experience conducting usability studies.
- Define and justify the number of users needed.
- Define inclusion and exclusion criteria for the users, such as: clinical conditions, level of physical functioning, level of cognitive functioning, previous experience using a similar technology, digital literacy, gender, educational level, and setting of recruitment, avoiding discrimination, among others, on the basis of sexual orientation, race, and class;
- Use reliable and valid instruments to characterise the users; for example, use the WHO Disability Assessment Schedule (WHODAS 2.0) to assess participants with a disability or the Quick Mild Cognitive Impairment Screen to characterise participants' cognitive function;
- Prepare a registration form for critical incidents.
- Chose a combination of complementary techniques from different methods, i.e., use at least a technique from the method of test and one from the inquiry method.
- Choose scales or questionnaires (if applicable) that are valid and reliable;
- Plan data analysis procedures that are appropriate for the type of data collected (qualitative vs. quantitative).
- Identify the appropriate tasks to be used for the usability assessment and write the script to be followed during the assessment.
- Prepare all the equipment needed for your assessment in advance and make sure everything is working and provide participants with appropriate and comfortable test facilities.
- Require ethical approval to conduct your research (please see section 7.6 of this deliverable)
- Prepare an informed consent form for the user to sign.

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- Identify the most adequate distribution on the space of the research team members (e.g., evaluator or observers).
- Use an observation room and recording room (if applicable).
- Always have in mind the characteristics of the user (SHAPES personas).

When reporting the results of the usability assessment by users, please do consider that you should report both on what you have done and why you have done it. Therefore, it is important to:

- Give the number of persons conducting the usability evaluation and details on relevant characteristics (age, gender, background, previous experience, appropriate communication skills); if this person needed training, details on the training procedures should be provided.
- Give the number of participants (i.e., the users who conducted the usability assessment) and detail inclusion and exclusion criteria as well as relevant characteristics, such as: clinical conditions, level of physical functioning, level of cognitive functioning, previous experience using similar technology, digital literacy, gender, educational level, and setting of recruitment;
- Provide evidence on the reliability and validity of all the instruments and measurement procedures used.
- State whether a critical incident occurred during the assessment and if so, describe its nature.
- Provide a justification for your choice of usability methods and techniques and how you combined data from different techniques.
- Describe the procedures and equipment used for data collection.
- Describe the number and nature of the tasks used for the usability assessment.
- Provide detail on your data analysis procedures.
- Describe any steps taken to make participants feel comfortable and at ease.

Particular attention should be given to end-users who are older persons so that the communication and the whole setting of the usability assessment provides a comfortable and pleasant experience. This will also maximise the probability of retrieving relevant information from the usability assessment. To provide practical and helpful recommendations to maximize the experience of older persons

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participating in the usability assessment, SHAPES' Personas were linked to potential barriers to the evaluation of usability and these to strategies to minimize the impact that these barriers may have on the results of the evaluation of usability (Table 19).

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Table 19 Personas (P), potential barriers to the users' evaluation of usability and consensus strategies to minimize users' main barriers to usability evaluation

Shapes' Personas	Examples of main barriers	Strategies to deal with the barriers
P1 - represents a distinctive group of younger older persons (65 – 75 years of age), that is characterized by generally good health and an active approach to life.	• No specific barrier.	Increase font size and contrast. Detachable or separate touchscreen in the case of robots
P2 - older persons with mild, but multiple chronic conditions, typically diabetes, hypertension, chronic respiratory disease, an oncological condition in remission.	• Perception barrier: visual impairment, decreased tactile acuity, general physical deconditioning.	Ensure accessibility for persons with disabilities, including but not limited to those with hearing and/or visual impairments to achieve an effective communication approach; Consider dividing the evaluation into parts and give a break to participants in between each part; Consider having a comfortable seat for the participant to rest/have a pause.
P3 - older persons with chronic musculoskeletal disorders, such as low back pain and osteoarthritis.	• Physical barrier: decreased balance, changes in motor control, decreased range of motion, pain. These limitations may be relevant for gesture-based interaction, where the range of movement, velocity and	Consider dividing the evaluation into parts and give a break to participants in between each part;

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	readiness for movement may be relevant.	Consider having a comfortable seat for the participant to rest/have a pause.
P4 - older persons with neurodegenerative diseases (P4), affecting cognition.	• Cognition barrier: decline in working memory, difficulties in concentrating or understanding instructions.	Carefully select usability protocols and tailor the evaluation/testing materials and sessions to include both the older person and the caregivers; Assure that the environment is as free as possible of distractors (unnecessary devices, posters or other material) but familiar to the person; Assure an effective communication: address the older person directly even if the cognitive capacity is diminished; gain the older person's attention (sit in front of and at the same level, maintaining eye contact); speak distinctively and at natural rate of speed; explain (or re-explain) who you are and what you'll be doing; gently provide assistance when the older person gropes for a word; use verbatim repetition or paraphrase sentences to facilitate comprehension; use simple direct wording; be aware of complimentary hearing/visual impairments that can add to the difficulties of understanding. Avoid usability testing

		protocols as the systematic usability scale instrument, think-aloud protocols and external mobile macro cameras attached to mobile testing devices as these may not be suitable and produce unreliable data [248]; The use of camera devices for video analysis in dementia cases requires obtaining the proper authorization of the older person's legal representative; The use of observation and recording of task completion rates have been reported as producing reliable results in individuals with dementia [248]; Performance metrics seem reliable.
P5 - lonely and/or socially isolated older persons.	• Motivation barrier: recruitment	Include a playful/enjoyable element in the assessment procedure [249]. Include a playful/enjoyable element in the assessment procedure [249], as entertainment games, small talk, play a song.
P6 - older persons with alcohol or drug dependency and severe	• Cognition barrier	As before.

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chronic conditions non-complying to medical recommendations.		
P7 - oldest old and frail.	• Cognition, Motivation, Physical, Perception barriers	Assure possible additional needs (e.g., time, individual support) for completing surveys [186].
P8 - deafblind older persons (older persons with a dual sensory impairment).	• Perception gap • Technology barrier • Communication barrier	Provide communications assistance (e.g., interpreter-guides), adequate training in the use of technology, ensure compliance with accessibility standards according to the CRPD (including GCs) and other disability rights instruments.

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7.4 SHAPES Tasks that Inform the Current Deliverable

The current deliverable is informed by the findings of other tasks, directly related to it. These are the Task 2.1: Understanding Older People: Lives, Communities, and Contexts, which has a deliverable in month 24; Task 2.5: SHAPES Personas and Use Cases, which has a deliverable in month 6; and Task 3.5: User Requirements for the SHAPES Platform, which has a deliverable in month 8.

Task 2.1 will undertake ethnographic studies across each of the SHAPES pilot sites, with up to 10 purposively selected individuals to reflect the range of older individuals in the different sites, allowing learning of how older individuals live across Europe and not seeing lives through the prism of SHAPES, but also understanding where the Platform would attain low impact results. Findings from this task will inform the design of the interface of digital solutions, but also the inspection methods and the usability assessment by users. Experts need to understand the users' characteristics and needs so that they assess digital solutions with that in mind. The assessment of usability by users' needs to be planned with the user in mind and results need to be put in context and analysed considering who the user is, what he needs, and wants.

Task 2.5 aimed to understand and analyse the user needs for SHAPES by developing personas, scenarios, and use cases and detailed the attributes, attitudes, behaviours, and characteristics of the user groups addressed by SHAPES. The personas will then be at the centre of user' stories, addressing how different stakeholders would use the SHAPES Platform, and identify specific features that enable the effective performance of relevant tasks. These personas and use cases illustrate the interactions between users and the SHAPES Platform to determine key requirements for functional and non-functional platform features and inform the interface design and the usability assessment of both the platform and the digital solutions. Specific recommendations were given in chapter 4 for the interface design considering the attributes, attitudes, behaviours and characteristics of the different Personas defined in this task. Furthermore, practical strategies to deal with the barriers during the assessment of usability by users were also given (Table 19) considering the 8 Personas defined in SHAPES.

Task 3.5, feeds results into deliverable 3.7, which is the first iteration of the SHAPES Platform User Requirements (URs) and will be completed in month 8 (June 2020). It is thereby important to note that it deals with overall requirements to the SHAPES platform and its operation in a multi-country setting. Hence, the term user requirements (related to the functionalities of the platform) is partly misleading since the related task should also consider more general requirements, relating for example to the country-specific legal and governance context or to ethical requirements not necessarily being defined by the user.

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Overall, in the first iteration of developing platform requirements, the following dimensions have been suggested:

- Functional Requirements (Reflecting User Needs)
- Non-functional Requirements:
- Security requirements
- Ethical & Legal requirements
- Health system requirements
- Business requirements
- Technical requirements

These dimensions will be specified in the next iteration – in close collaboration with the project consortium and building on the interaction with the use cases, replicating sites, and users. The fact that both the present deliverable and deliverable 3.7 must be completed at very close dates (June and July 2020, respectively) an in-depth analysis of the specifications of the identified dimensions will be performed at a later stage. In addition, this delivered was also informed by work developed in work package 8 - SHAPES Legal, Ethics, Privacy and Fundamental Rights Protection and on documents produced within the SHAPES project such as the SHAPES Terminology report and the SHAPES Accessibility Report produced by The World Federation of The Deafblind and the European Union of the Deaf.

7.5 SHAPES Tasks Informed by the User Interface Design and Usability Assessment Guidelines

This deliverable tackles the definition of the SHAPES User Experience (UX) and design guidelines that are to be followed when developing and implementing both the SHAPES platform and the digital solutions that will interact with the user, which are to be developed and assessed within the work packages 4 and 5, namely:

- **Task 4.5:** Human Interaction and Visual Mapping; This task implements human-friendly interaction mechanisms based on Automatic Speech Recognition and Natural Language Processing (NLP), capable of making SHAPES engage in “normal” conversations (audio and text) with its users.
- **Task 4.6**: SHAPES Authentication, Security and Privacy Assurance; This task designs and develops SHAPES Authentication Mechanisms,

implemented by SHAPES partners technology providers and demonstrated in the pilot activities.

- **Task 5.2:** Solutions for SHAPES Intelligent Living and Care Environment; This task adapts existing IoT-based platforms and components and eHealth applications to be integrated into the SHAPES TP.
- **Task 5.3:** Applications Suite for Healthy Ageing; This task consists of the adaptation of various applications and solutions developed by SHAPES partners that can be combined into suites meeting a user's needs, conditions, and profiles.
- **Task 5.4:** Robotics and Assistive Technologies; This task integrates the robots and assistive technologies with the SHAPES technological platform, by adapting those technologies to become environmental-aware (share information with IoT-enabled devices).
- **Task 5.5:** Decision Support and Risk Assessment and Prediction Services; This task will integrate multi-model decision support tools for health and care providers with the SHAPES platform, integrating guideline-based decision support system (DSS), experience-based DSS and case-based DSS and including user friendly visual analytics that support reports generation.
- **Task 5.6:** Solutions for Health and Care Service Providers; Integrate existing health and care platforms used by service providers with the SHAPES technological platform, bringing mechanisms to improve the care professionals' connection or communication with older individuals.
- **Task 5.7:** Lifestyle Management and Wellbeing Assessment Solution; In this task, a lifestyle management and wellbeing assessment is carried out, involving individual models to monitor various health and fitness parameters, provided by wearables, home devices, social activity apps, emotion readers, eHealth sensors, and incorporating intelligent data processing for the recognition of behavioural trends and specific services for personalised guidance on healthy lifestyle and disease prevention.

7.6 Ethics

The SHAPES Legal, Ethics, Privacy and Fundamental Rights Protection are defined in work package 8 of SHAPES, which is led by LAUREA and detailed information is provided within the respective deliverables. This section simply highlights the need to take these aspects into account when designing and evaluating SHAPES platform and digital solutions. An ethical self-assessment for the research conducted on each work package was developed by LAUREA.

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Below we transcribed the indications given in this self-assessment guide that apply to the activities conducted when designing digital solutions and evaluating their usability.

Inspection methods and usability evaluation by end-users employ human participants. Therefore and, according to the ethical self-assessment guidance, the following activities should be taken:

#1 Always respect human dignity and the intrinsic value of the individuals.

#2 Provide accessible consent forms to the participants, including an information sheet specifying the nature of the research. The template for the consent and information sheets are available in work package 8 and deliverable D8.2. The documents have to be written in the participant's language. The researcher/pilot organisation will keep the consent forms on file in a safe place until the end of the project.

#3 A written research plan must be provided and available on request, including details of the recruitment, types of vulnerability and diseases, inclusion and exclusion criteria and informed consent procedures. If people unable to provide consent will be involved, the procedures for obtaining approval from the legal representative must be described in detail. Also, the plan must demonstrate appropriate efforts to ensure fully informed understanding of the implications of participation.

#4 Ethics approvals by local authorities must be acquired and kept on file (e.g., when involving vulnerable persons and persons unable to give consent. This also applies in the situation with Covid-19 pandemic.

#5 The methods and tools to be used in co-creation with the older persons will be chosen carefully by considering accessibility needs and avoid creating a burden for vulnerable participants, or any risk for stigmatisation. All direct costs for participants are to be covered by the project.

In addition, the research conducted when designing and assessing digital solutions may involve the collection of personal data. When this happens, the following has to be done:

#1 Informed consent forms collected from the participants are the general prerequisite for this data processing.

#2 Researchers should provide details regarding the procedures of the collection, storage, protection, retention, transfer and destruction or re-use of data, as well as those regarding data safety procedures, data transfers to third countries and tracking and observing methods. This activity is part of the data management plan.

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#3 The SHAPES data processing description is filled out and uploaded to Teams.

#4 The Data Protection Officer and Data Owner have been nominated.

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8 Consensus Generating Procedure on User Interface Design Guidelines and Usability Assessment

In previous chapters, we have synthetized existing evidence on user interface design, usability inspection methods, and usability assessment by users. We also analysed and summarised existing evidence to provide up to date, evidence-grounded, practical recommendations for SHAPES platform and digital solutions. This work took place between February and June 2020 as established in the SHAPES project Grant Agreement. Nevertheless, during the preparation of this deliverable, it was felt that additional steps were needed to generate a solid consensus around the set of procedures that should be used for user interface design, usability inspection methods, and usability assessment by users in the SHAPES project. We believe that there is a need to define consensus around two sets of procedures: a minimal set that is mandatory for all SHAPES solutions and platform, and the second set of procedures that is desirable, but not mandatory to follow. The decision to follow or not these recommendations may depend on the nature of the digital solution or the target users. However, to achieve this level of consensus and commitment, further steps are needed that go beyond the time course of this deliverable. This would add value to the SHAPES project and further contribute to the sense of coherence and uniformity, as well as to the overall quality of the work conducted.

This chapter presents: (i) the general methodology that will be used to generate consensus around interface design, usability inspection methods, and usability assessment by users and generate the two sets of recommendations, and those involved in this process; (ii) a synthesise of the recommendations presented on this deliverable for user interface design guidelines, inspection methods and usability evaluation by users and how they will inform the consensus generating methodology; and (iii) the expected results from the consensus methodology and how it will inform the work of the partners developing the SHAPES platform and digital solutions, and a timetable for the different steps of this consensus methodology.

8.1 General Methodology for Generating Consensus on User Interface Design, Inspection Methods and Usability Evaluation by Users

To generate a consensus on the methods, procedures, and instruments for user interface design and usability evaluation, we adapted a methodology previously

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reported [250]. This consensus will promote a sense of consistency and coherence within the SHAPES project and, conceivably, improve the transparency and quality of the work conducted. This process involves 5 phases, which are next described:

- **Phase 1:** Detailed review and analysis of existing literature (already presented in chapters 4 to 6 of this deliverable);
- **Phase 2:** Detailed analysis of information already generated in the SHAPES project (partially performed as deliverables 2.1 and 3.7, which inform the current deliverable, but not fully completed yet);
- **Phase 3:** Discussion with SHAPES partners on the relevance and completeness of the guidelines and recommendations presented in chapters 4, 5 and 6 (already performed), resulting in an aggregated and comprehensive list of recommendations on user interface design recommendations, and inspection methods and usability assessment by users;
- **Phase 4:** A modified Delphi survey with SHAPES partners will be conducted to generate consensus on user interface design recommendations, and inspection methods, and usability assessment by users;
- **Phase 5:** Final consensus.

8.1.1 Detailed Review and Analysis of Existing Literature

This step was already conducted, and the results of the review and analysis of existing evidence are presented in chapters 4, 5, and 6 of this deliverable.

In chapter 4, we present interface design principles or heuristics to promote a coherent, intuitive, natural, and rewarding user interaction. Combining widely recognized and accepted heuristics found during a comprehensive search of existing literature we generated 22 heuristics. Then, and to help achieve the principle defined in each heuristic, we proposed a set of practical recommendations for each one of the 22 heuristics and different digital solutions and users. We also identified relevant user interaction and accessibility standards to further inform the user interface design, leading to a comprehensive list of recommendations on user interface design.

Chapter 5 characterises existing procedures for user inspection of digital solutions, covering the characteristics of the evaluators involved in the usability inspection, the current usability inspection methods, the instruments used to support the usability inspection as well as the heuristics and tasks used in that

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assessment. The data on this section will be used to create a list of recommendations to consider when planning, conducting, and reporting on the inspection of digital solutions.

Chapter 6 presents an in-depth analysis of current practices on usability by end-users, covering the characteristics of those involved in the assessment of usability (the individuals who conduct the usability evaluation and the individuals who are asked to evaluate the usability of a product or service); the procedures and instruments used (namely the activities that participants are asked to perform when evaluating the usability of a product or service and the set of techniques used to perform formative usability evaluation, (i.e., usability evaluation or testing to improve usability) at any stage of the product or service development and the test environment, i.e., the environment where the evaluation of usability takes place. The data on this section will be used to create a list of recommendations to consider when planning, conducting, and reporting on usability assessment by users.

Furthermore, recommendations to promote the methodological quality of studies related to inspection methods and users' assessment of usability are also provided as well as general principles and guidance for usability assessment by end-users and practical recommendations to facilitate usability assessment by older persons.

Overall, each of the chapters 4, 5 and 6 generated a list of recommendations that will be further completed in the next two steps of the consensus generating procedure.

8.1.2 Detailed Analysis of Information Already Generated in the SHAPES Project

This step consists of a careful analysis of deliverables already developed by SHAPES partners, particularly those from tasks expected to inform the present deliverable: deliverables 2.1, 2.5 and 3.7 (as previously referred in chapter 7). This task will be undertaken as deliverables are completed. Up until this moment, only deliverable 2.5 has been completed. Recommendations generated within chapters 4, 5 and 6 will be further complemented with relevant information from these deliverables and from other relevant documents such as the SHAPES Accessibility Report.

8.1.3 Discussion with SHAPES Partners

This deliverable was shared with SHAPES partners participating in work package 5, but also with SHAPES partners leading tasks 2.1, 2.5 and 3.7 and partners involved in the development of the SHAPES technological platform. Then a

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meeting with all of them was also scheduled. Partners were asked to provide oral or written feedback on chapters 4, 5 and 6, more specifically:

- **Chapter 4**
  - Is anything missing?
  - Should anything be deleted?
  - Do you agree with the 22 heuristics?
  - Please do give contributions to recommendations.
  - Would you like to further contribute to any subsection of this chapter?
- **Chapters 5 and 6**
  - Is anything missing?
  - Should anything be deleted?
  - Would you like to contribute to any subsection of this chapter?

This information was added to that collected in the previous phases and used to further complete recommendations and guidelines, resulting in aggregated and comprehensive lists of recommendations on: (i) user interface design guidelines, ii) inspection methods and (iii) usability assessment by users, that will be used in the following phases of the consensus generating procedure.

8.1.4 Modified Delphi Survey

The procedures to prepare for the modified Delphi study will begin in September 2020. First, partners from the SHAPES project as well as partners from other European Union health and technology-related European projects will be sent an invitation to enter this phase of the consensus generating procedure. Those that accept to participate will be asked to identify up to 3 staff members willing to fill the Delphi survey and who are experts in user interface design, inspection methods or usability assessment by users. A list of inclusion and exclusion criteria will be sent with the invitation to guide them. Then, each one of the lists of recommendations generated in the previous steps of this consensus generating procedures will be sent to those accepting to participate and meeting the inclusion and exclusion criteria. Each participant will be asked to rate each recommendation/item on a scale of 1 to 9 (1=not at all appropriate to 9=completely appropriate) and will also be allowed to comment on each item. Results will then be analysed by the UAVR team in terms of mean and standard deviation and percentage of participants rating each item on each category of the

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scale. Consensus on the inclusion of 1 recommendation will be considered when 70% or more participants scored the item as 7 to 9. Consensus on the exclusion of 1 item will be considered when 70% or more participants scored an item as 1 to 3 and less than 15% of participants scored the item as 7 to 9 [251], [252]. In addition to inclusion and exclusion of recommendations, we hope to be able to define a hierarchy of recommendations: mandatory (those scoring 7 to 9 by at least 70% of participants) and those desirable but not mandatory (those scoring 4 to 6 and not meeting the criteria for mandatory).

In a second round of the Delphi survey, participants will be provided with the results from round one, including the hierarchy of recommendations and the three sets of recommendations (mandatory, desirable, and not relevant/excluded), and asked to comment on them and to classify each using one of four options: keep in this category (mandatory or desirable), move to another category, discard, or no opinion. They will also be asked to add any items they believed had been missed.

For each round, a minimum response rate of 70% will be required to consider the round valid [253]. Reminders will be sent at the end of the first and second weeks to those that had yet to reply to the survey, both on rounds 1 and 2. Details on age, academic background, expertise, and work published in the area will be collected in order to characterize the sample participating in this Delphi.

At the end of the second round, the UAVR team will review the feedback from participants and adjust the recommendations accordingly. It is expected that at the end of this process there will be two sets of recommendations (a mandatory one and a recommended but not mandatory) for each one of the core areas: interface design, inspection methods, and usability assessment by users.

The results of this consensus generating procedure will be compiled in an internal SHAPES report.

8.2 Consensus Generating Procedure Timetable

Table 20 presents the timetable for the activities that will take place after the submission of the present deliverable and that extend the work of task 5.1 beyond its time course.

Table 20 Consensus generating procedure timetable

Task	Sept. 2020	Oct. 2020	Nov. 2020	Dec. 2020	Jan. 2020	Feb. 2021	Mar. 2021
	M11	M12	M13	M14	M15	M16	M17
Formatting the final list of recommendations as a survey	■						
Invite SHAPES partners and partners from other European projects and identify participants		■					
Delphi survey – 1st round			■				
Data analysis of Delphi 1st round (preliminary results)				■			
Delphi survey – 2nd round					■		
Data analysis of Delphi 2 nd round						■	
Final report							■

Legend: M – month as counted for SHAPES project execution; Setp. – September; Oct. – October; Nov.- November; Dec. – December; Jan. – January; Feb. – February; Mar. – March.

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9 Conclusion

This deliverable synthetized existing evidence on user interface design principles and heuristics, inspection methods of evaluation of usability, and users' evaluation of usability. It builds on existing literature on these topics, crosses it against findings of good practices and discussions with SHAPES partners to define consensus guidelines and recommendations that will be employed in SHAPES and guide the user interface design and usability evaluation of the technological solutions (WP5). It is expected to help standardising procedures and reporting, boost the quality of the SHAPES platform and digital solutions and to promote an enjoyable experience for participants involved in user interface designing and in evaluating usability.

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Appendix: Ethical Requirements of D5.1

The focus of this compliance check is on the ethical requirements defined in D8.4 and having impact on the SHAPES solution (technology and related digital services, user processes and support, governance, business and ecosystem models). In the left column there are ethical issues identified and discussed in D8.4 (corresponding D8.4 subsection in parenthesis). For each deliverable, report on how these requirements have been taken into account. If the requirement is not relevant for the deliverable, enter N / A in the right-hand column.

Ethical issue (corresponding number of D8.4 subsection in parenthesis)	How we have taken this into account in this deliverable (if relevant)
Fundamental Rights (4.1)	By making recommendations that are person-centred and that respect the person at all stages.
Biomedical Ethics and Ethics of Care (4.2)	By making recommendations that respect those involved in user interface design and usability assessment and that aim to avoid hurt or discomfort resulting from them.
CRPD and supported decision-making (4.3)	By making recommendations that respect the will and preferences of persons in general and of older persons, in particular, and by highlighting the need to conduct an ethical self-assessment, and the need to guarantee the anonymity and confidentiality of data at all stages.
Capabilities approach (4.4)	By making recommendations concerning interface design and usability assessment that take into account older persons' capabilities.
Sustainable Development and CSR (5.1)	By making recommendations that respect and protect human rights.
Customer logic approach (5.2)	By making recommendations on user interface design and usability assessment that are user centred, i.e.,

	that involve the user from the very beginning of the process.
Artificial intelligence (5.3)	Not applicable.
Digital transformation (5.4)	By making recommendations on user interface design and usability assessment that are user centred, i.e., that involve the user from the very beginning of the process and aim to improve the overall quality of the development and assessment process of the SHAPES platform and digital solutions.
Privacy and data protection (5)	By providing specific heuristics on privacy for the development of SHAPES platform and respective digital solutions, and in terms of assessment by highlighting the need to conduct an ethical self-assessment, and the need to guarantee the anonymity and confidentiality of data at all stages.
Cyber security and resilience (6)	By providing specific heuristics for user interface design on privacy and security.
Digital inclusion (8.1)	By making recommendations on user interface design and usability assessment that are user centred, i.e., that involve the user from the very beginning of the process and that take into account the heterogeneity of older persons.
The moral division of labor (8.2)	By making recommendations on user interface design and usability assessment that are user centred, i.e., that involve the user from the very beginning of the process and that take into account the heterogeneity of older persons.

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Care givers and welfare technology (8.3)	Not applicable.
Movement of caregivers across Europe (8.4)	Not applicable.

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