Programa de Doctorado en Estadística, Optimización y Matemática Aplicada

USER EXPERIENCE EVALUATION FOR PEOPLE WITH AUTISM SPECTRUM DISORDER

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INFORMA/N:

Que Dña. *Katherine Ivone Valencia Castillo* ha realizado bajo nuestra supervisión el trabajo titulado **User Experience Evaluation for People with Autism Spectrum Disorder** conforme a los términos y condiciones definidos en su Plan de Investigación y de acuerdo al Código de Buenas Prácticas de la Universidad Miguel Hernández de Elche, cumpliendo los objetivos previstos de forma satisfactoria para su defensa pública como tesis doctoral.

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RESUMEN

Las personas con Trastorno del Espectro Autista (TEA) tienen mayores desafíos en el desarrollo de sus habilidades comunicativas y sociales. Estas personas tienden a disfrutar de las interacciones con las computadoras, ya que estas interacciones se dan en un entorno seguro y estructurado.

Diversos estudios se han dedicado a desarrollar sistemas y/o aplicaciones de software para personas con TEA, intentando que sean lo más accesibles y usables para sus usuarios. Sin embargo, estos estudios no presentan suficiente detalle en las evaluaciones y evidencia empírica incluidas en sus investigaciones, en un contexto de usabilidad y experiencia de usuario, por lo que es necesario formalizar el proceso de evaluación de la experiencia de usuario cuando se trabaja con personas con TEA.

Se ha propuesto y seguido un proceso de 7 etapas para la creación de una metodología de evaluación de la experiencia de usuario para productos, servicios y sistemas utilizados por personas con TEA. Estas etapas describen y detallan los procesos realizados así como la información recopilada, incluyendo la realización de revisiones sistemáticas, la creación de un conjunto de pautas de diseño, una propuesta para la particularización de 9 factores UX para personas con TEA, la selección y adaptación de métodos de evaluación UX considerando las necesidades de las personas con TEA, y la validación de la metodología propuesta.

En este documento establecemos, validamos y aplicamos una metodología para evaluar la experiencia de usuario de productos, sistemas y servicios utilizados por personas con trastorno del espectro autista. Esta metodología propone 3 etapas secuenciales, una etapa de planificación, una etapa de ejecución y una etapa de análisis de resultados, que contribuyen a la correcta selección de participantes, evaluadores, métodos y diseño de los experimentos, así como la ejecución de los métodos seleccionados y el procesamiento de los resultados obtenidos. La implementación de la metodología propuesta tiene como finalidad obtener conocimientos valiosos que puedan ayudar a los usuarios con TEA a mejorar su experiencia, y por ende su calidad de vida, a través del uso de la tecnología.

Palabras claves:

Evaluación de la experiencia del usuario, Experiencia del usuario, Metodología de evaluación, Métodos de evaluación, Trastorno del Espectro Autista (TEA), Usabilidad.

ABSTRACT

People with Autism Spectrum Disorder (ASD) have greater challenges in the development of their communication and social skills. They tend to enjoy interactions with computers, as these interactions are in a safe and structured environment.

Several studies have been dedicated to the development of software systems and/or applications for people with ASD, trying to be as accessible and usable as possible for their users. However, these studies do not present enough detail in the evaluations and empirical evidence in their research, in a context of usability and user experience, therefore it is necessary to formalize the user experience evaluation process when working with people with ASD.

A 7-stage process has been proposed and followed for the creation of a specific user experience evaluation methodology for systems products or services used by people with ASD. These stages describe and detail the processes to follow and information to be collected, such as carrying out systematic reviews, creating a set of design guidelines, a proposal for the particularization of 9 UX factors for people with ASD, selecting and adapting UX evaluation methods that fit the needs of people with ASD, and validating the methodology.

In this document we stablish, validate and apply a methodology to evaluate the user experience for people with autism spectrum disorder. This methodology proposes 3 sequential stages, a planning stage, an execution stage, and a results analysis stage, which contribute to the correct selection of participants, evaluators, methods and design of the experiments, as well as the execution of these methods and the processing of the results to obtain valuable insights that can help the users with ASD to improve their experience, and thus their quality of life, through the use of technology.

Keywords:

Autism Spectrum Disorder (ASD), Evaluation Methodology, Evaluation Methods, User Experience, User Experience Evaluation, Usability.

CONTENTS

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1 INTRODUCTION

Autism Spectrum Disorder (ASD) is a developmental disorder that affects people's communication and behavior. The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [1] states that autism spectrum disorder (ASD) as a condition characterized by deficits in two core domains: (1) social communication and social interaction and (2) restricted repetitive patterns of behavior, interests, and activities.

The use of technology and software applications facilitates teaching language and social skills to people with ASD [2]. Studies such as the proposed by Kapp [3] mention that people with autism spectrum disorder tend to have fun and participate more when technology is used, as these provide a safe and reliable environment.

As users with ASD have specific characteristics, it is important that the process to evaluate the User eXperience (UX), as well as the evaluation methods and instruments, are selected and adapted considering them, to ensure a positive and rewarding experience when interacting with systems, products or services.

Several studies have considered and evaluated the user experience in systems, products and/or technological applications used by people with ASD. Most of these studies do not present sufficient details in the evaluations and lack of empirical evidence in the research carried out [4].

Despite this, there are investigations that have proposed various evaluations of the usability and/or user experience of systems, products and/or technological applications developed for people with autism spectrum disorder, through the use of questionnaires, focus groups [5], under established scales [6] and/or use of Nielsen heuristics adaptations [7]. These studies demonstrate different possibilities to evaluate user experience and/or usability in systems and/or products used with people with ASD, but empirical details and evidence are lacking.

For this reason, the final goal for this doctoral research it is to establish and validate a methodology to evaluate the user experience for people with autism spectrum disorder, as there is a need for a formal methodology built upon the needs and characteristics of users with ASD, providing proper guidelines and evaluation methods. To develop the methodology a 7-stage process has been proposed and followed.

In this development process, we have carried out a system literature review [4], which aimed to know the current state of research regarding the impact that technology has on people with ASD when developing their skills, and how these technologies consider and evaluate the user experience, usability and accessibility. Then, a systematic review of 11 papers has been carried out [8], with the objective of understanding how these studies characterize the difficulties of people with ASD, how these characteristics are used to design their proposals, the results obtained and possible recommendations, in order to determine design guidelines and best practices for future interventions technologies that meet specific needs in people with ASD.

Then, we searched and selected of methods of user experience and/or usability used in the literature that could be applied in systems or products focused on people with autism

spectrum disorder. These methods have been selected and adapted considering the characteristics of people with ASD.

After, a preliminary proposal of the methodology to evaluate the user experience in people with ASD has been proposed [9]. Also, given the need to formalize the user experience evaluation process in products, systems or service focused on people with ASD, the UX factors defined by Morville have been particularized [10], considering the characteristics, affinities and needs of people with ASD, and design guidelines and/or recommendations found in the literature [11].

The methodology was reviewed and validated through the opinion of three experts in UX and later via an expert judgement validation by 22 experts with knowledge on UX, ASD and/or both, and the final version of the methodology was published [12].

Finally, the methodology was applied over two use cases, an application designed for people with ASD, and a widely used website, where we managed to generate extensive UX reports that detected potential problems and gives recommendations on how to improve the users experience for people with ASD, which highlights the benefits of using the methodology.

A quantitative and qualitative research methodology has been followed, since data collection methods are used to obtain the perspectives and points of view of the participants, something useful when working with people with ASD. The scope of the research is descriptive, since this research aims to examine a topic that has not been studied and documented.

The document is organized as follows: section 2 describes the problem statement; section 3 sets out the objectives of a research; section 4 describes the methodology of doctoral research; section 5 shows the work plan; section 6 explores the key concepts related to the research; section 7 shows the results obtained from the systematic literature review; section 8 shows a review of the literature and design guidelines proposed based on the information collected; section 9 introduces and describes the process of creating the methodology; section 10 presents our proposal of 9 UX factors for people with ASD; section 11 describes a set of 6 UX evaluation methods adapted to the needs of people with ASD; section 12 presents a proposal of the user experience evaluation methodology for people with ASD; section 13 presents an expert judgement validation; section 14 presents two case studies applying the methodology; and section 15 presents conclusions and future works.

2 PROBLEM STATEMENT

According to ISO 9241-210 [13], user experience is defined as: “user’s perceptions and responses that result from the use and/or anticipated use of a system, product or service”. The user experience: “includes all the users’ emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviors and accomplishments that occur before, during and after use”. Providing positive experiences, ensuring comfort in the use of products, systems or services, taking into account the needs of people with ASD is a priority when interacting with them.

Few studies have developed and evaluated user experience in this context, and many of these studies did not provide enough detail about the use of these concepts, as evidenced in previous work [4]. This shows us that many studies have deficiencies in validating the UX, as well as lack of empirical evidence when working with people with ASD.

Studies such as those proposed by De Los Rios [14], Backman et al. [5], Khowaja and Salim [15], Vallefuoco et al. [16] and Caria et al. [6] propose various evaluations of the usability and/or user experience of systems and/or technological applications used by people with autism spectrum disorder in an educational context.

De Los Rios [14], suggests evaluating the usability of the application used based on users' eye tracking. In Backman et al. [5], a questionnaire after the use of the system and focus groups has been applied to the users, parents and teachers of the users who participated in the case study. Khowaja and Salim [15], evaluated their proposed solution by proposing an adaptation of the heuristics proposed by Nielsen [7] to the context of the study. Vallefuoco et al. [16], performed a usability test with children under the methodology proposed by Moreno Ger [17]. And finally, Caria et al. they used the "System Usability Scale" (SUS) [18] to evaluate the usability of their applications.

We have reviewed proposals for instruments to evaluate the usability and/or user experience of systems and/or applications for people with ASD through heuristic evaluations, as proposed in the “Heuristics to Evaluate Interactive Systems for Children with Autism Spectrum Disorder (ASD)” [19]. In this research, Khowaja. K and Salim. SS [19] propose a set of 15 heuristics, adaptation of Nielsen's heuristics [7], to inspect features such as visibility, match, consistency, recognition, minimalist, control, error, flexibility, recover, documentation, personalization, screens, responsiveness, track and multi-modalities.

Studies presented demonstrate different approaches to assess user experience and/or usability of the systems and/or applications used in their research. But these studies don’t provide enough details of the evaluations performed, and many of these studies do not present empirical evidence of positive results when working with people with ASD [4], so there is no formal process to evaluate the user experience in people with ASD. Therefore, the following doctoral research questions arise:

- Which user experience and accessibility elements/methods are considered when using technology for skill learning with people with autism spectrum disorder?
- In what way does the use of technology support skill development of people with autism spectrum disorder?
- How to define a user experience evaluation methodology for people with autism spectrum disorder?

- How to validate the user experience evaluation methodology for people with autism spectrum disorder?

3 OBJECTIVES

Based on the research questions, the following objectives are raised.

3.1 General Objectives

Establish a methodology to evaluate the user experience for people with autism spectrum disorder.

3.2 Specific Objectives

- Determine the use of technology in people with autism spectrum disorder.
- Identify appropriate methods to evaluate user experience for people with autism spectrum disorders.
- Formalize a methodology to evaluate the user experience for people with autism spectrum disorder.
- Validate the methodology through expert judgment and case studies.

4 METHODOLOGY

The research methodology to be followed is under a quantitative and qualitative approach. As defined by Hernandez [20], this approach uses data collection methods in order to discover and refine research questions in the interpretation process. Qualitative research is based on an inductive, recurring process, multiple subjective realities are analyzed, and it has no linear sequence, so data collection consists of obtaining the perspectives and points of view of each participant. In addition, qualitative research provides depth to the data, dispersion, interpretative richness, contextualization of the environment or environment, details and unique experiences.

Considering the research approach, the scope of the research will be descriptive, because this research aims to specify the characteristic and profile of the people and group, after an analysis. Given these investigative lines, research questions are raised (as shown in section 2), but a research hypothesis has not been formulated.

In order to respond to the research questions raised, it is that steps and activities have been established to be carried out during the course of the investigation, as detailed below:

1. Systematic Literature Review: Use of technology with people with autism spectrum disorders.
2. Literature Review: Evaluation of the user experience with people with autism spectrum disorders.
3. Field observation: Approach social situations and keep an active role in the context we want to work. Always being attentive to the details, events and interactions that may occur.
4. Formulation of the proposed evaluation methodology.
5. Case Studies: Select a system, product or service to be evaluated and apply the proposed methodology to evaluate user experience on people with autism spectrum disorder.
6. Validation of the proposed evaluation methodology.
7. Refine the proposed evaluation methodology.

5 WORK PLAN

The following work plan has been designed according to the steps proposed on the methodology. Table 1, Table 2, Table 3 and Table 4 present the work plan from 2019 to 2022.

Table 1. First Year Work Plan

First Year (2019 - 2020)										
	Thesis seminar					**Thesis project**				
Activities	**Ag**	**Sep**	**Oct**	**Nov**	**Dec**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
1. Systematic literature review of the impact of technology on people with ASD.	X	X	X							
2. Literature review of technology-based learning for people with ASD.				X	X					
3. UX factors characterization for people ASD.						X	X			
4. Selection of candidate UX methods								X	X	
5. Preliminary proposal of the evaluation methodology									X	X

Table 2. Second Year Work Plan

Second Year (2020 - 2021)										
	Thesis					**Thesis**				
Activities	**Ag**	**Sep**	**Oct**	**Nov**	**Dec**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
6. UX candidate methods particularization.	X	X	X							
7. Formalization of the evaluation methodology			X	X	X	X				
8. Particularization of UX factors for people with ASD							X	X	X	X

Table 3. Third Year Work Plan

Third Year (2021 - 2022)												
	Thesis					**Thesis**						
Activities	**Ag**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
8. Particularization of UX factors for people with ASD	X	X	X	X								

6. UX candidate methods particularization.					X	X						
9. Evaluation methodology specification.				X		X	X					
10. Validation: expert judgment								X	X	X		
11. Validation: case studies										X	X	X
12. Refining of the evaluation methodology											X	X

Table 4. Fourth Year Work Plan

Fourth Year (2022)				
	Thesis			
Activities	**Ag**	**Sep**	**Oct**	**Nov**
11. Validation: case studies	X	X	X	
12. Refining of the evaluation methodology	X	X		
13. Finalization of thesis report			X	X

Table 5 present the articles submitted to ISI indexed journals:

Table 5. Articles Submitted

Journal ISI	**Title**	**Date**	**Status**
Sensors	The Impact of Technology on People with Autism Spectrum Disorder: A Systematic Literature Review.	October 16, 2019.	Published. The final version was accepted on Oct 11, 2019.
Applied Sciences	User Experience Factors for People with Autism Spectrum Disorder	November 8, 2021.	Published. The final version was accepted on November 3, 2021.
Applied Sciences	A Methodology to Evaluate User Experience for People with Autism Spectrum Disorder	November 8, 2022	Published The final version was accepted on November 4, 2022.

Table 6 present the papers submitted to conferences:

Table 6. Papers Submitted

Conference	**Title**	**Date**	**Status**
HCI International 2020	Technology-based Learning for People with Autism Spectrum Disorder	December 1, 2019.	Published and presented. The final version was accepted on Jane 31, 2020.

HCI International 2021	A Preliminary Methodology to Evaluate the User Experience for People with Autism Spectrum Disorder	November 9, 2020.	Published and presented. The abstract was accepted on November 9, 2020.
HCI International 2022	A property Checklist to Evaluate the User Experience for People with Autism Spectrum Disorder	January 31, 2022.	Published and presented. The abstract was accepted in February 2022.

6 KEY CONCEPTS

6.1 Autism Spectrum Disorder

In 1943 Leo Kanner [21] defined the term autism as a developmental disorder characterized by delays in language, stereotyped movements, self-stimulating behaviors, and alterations in relationship, communication, and flexibility. The concept of autism was considered conceptually different from the Asperger Syndrome described by Hans Asperger in 1944 [22], given its qualitative differences. In 1979 Lorna Wing and Judith Gould [23], stated that despite the qualitative differences between Autism and Asperger's Syndrome, people with these conditions share difficulties in: communication, social interaction and cognitive rigidity.

Since 2013, in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [1], both concepts are considered within the broader definition of Autism Spectrum Disorder (ASD), as a condition characterized by deficits in two core domains: (1) social communication and social interaction and (2) restricted repetitive patterns of behavior, interests, and activities.

Some characteristics that people with ASD can present are: a tendency towards visual and structured thinking [24], delay of fine motor skills development [25], difficulties when generalizing skills to real-world contexts [26], susceptibility to experiencing depression and frustration [27], exhibit of hyper- or hypo-reactivity to sensory input or an unusual interest in sensory aspects of the environment [1].

People with ASD may or may not present secondary symptoms such as intellectual disability, low tolerance for frustration, lack of verbal language, and motor problems. The DSM-5 establishes three categories of severity for ASD [1] based on the degree of support that the person needs, which varies from level 1 "Requires support" to level 3 "Requires very substantial support".

6.2 User Experience

The international standard on ergonomics of human system interaction, ISO 9241-210 [13], defines user experience as "user's perceptions and responses that result from the use and/or anticipated use of a system, product or service". It considers that UX "users' perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviors, and accomplishments that occur before, during and after use". In other words, the user experience is the degree of "satisfaction" that the end user has with the system or service after using it, that is based on each of the interactions that he or she has.

In addition, the ISO 9241-210 [13] standard mentions that UX is a "consequence of brand image, presentation, functionality, system performance, interactive behavior, and assistive capabilities of a system, product or service. It also results from the user's internal and physical state resulting from prior experiences, attitudes, skills, abilities and personality; and from the context of use".

One part of UX is usability, this concept is defined by the ISO 9241-11 standard [28] as the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." The concept of usability is related to the fulfillment of tasks and the satisfaction that users

experience. Consequently, a higher degree of usability of a product or system after user interaction also leads to a better user experience.

6.3 Accessibility

The international standard on ergonomics of human system interaction, ISO 9241-171 [29] defines accessibility as the "extent to which products, systems, services, environments, and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use". In other words, accessibility is the condition that environments, services, processes, and objects (everything that involves an interaction) must meet, which must be understandable and usable by the broadest range of people, regardless of their capabilities.

6.4 UX Models

Multiple authors have defined UX and usability models, which are focused on providing indicators to measure the "satisfaction" of a user with the interaction between him and the system or product. Some examples are: (1) Guidance on Usability from The International Standard on Ergonomics of Human System Interaction [28], that defines three aspects to consider: effectiveness, efficiency and satisfaction, (2) Jacob Nielsen [30], that described six attributes to consider: Learnability, efficiency, memorability, errors and satisfaction, (3) Llúcia Masip et al. [31] which describes eleven facets to consider: dependability, usability, playability, accessibility, plasticity, communicability, cross-cultural, emotional, desirable, useful and findable, and (4) Peter Morville presented 7 factors to consider: useful, usable, desirable, findable, credible, accessible and valuable.

6.5 User Experience Honeycomb

Peter Morville in 2004 created the User Experience Honeycomb model [10], which includes seven factors. It is stated that by complying with these factors, the user experience is significant and valuable. These factors are: useful (its content is original and satisfies a need), usable (the product is easy to use, simple, familiar and easy to understand), desirable (the image, identity, brand, and other design elements evoke emotions and appreciation towards the product), findable (the information needs to be findable and easy to navigate), accessible (the content is accessible to people with disabilities), credible (the products need to be trustworthy), and valuable (an added value is generated from the product).

6.6 UX Evaluation Methods

A system or product can be evaluated using usability and/or UX evaluation methods. UX evaluation methods focus on detecting how the user feels about the interaction with the evaluated system or product [32]. On the other hand, usability evaluation methods are "a procedure composed of a series of well-defined activities for the collection of data related to the interaction of the end user with a software product and/or how a specific feature of this product of software contributes to achieving a certain degree of usability" [33]. Considering that the concept of user experience includes usability, we have chosen a set of UX evaluation methods that will help us effectively evaluate the UX and usability on systems, products or services used by people with ASD.

For our proposed methodology for evaluating systems, products, or services for people with ASD, we have selected evaluation methods under the following usability method classifications, as defined by Fernandez et al. [33]:

- *Inspections*: Reviews conducted by a group of evaluators using their expert judgment, where the participation of users of the system or product is not included.
- *User tests:* Users evaluate the product or system after interacting with it.

6.7 Business Process Model and Notation

Business Process Model and Notation (BPMN) is a process modeling standard that makes it possible to graphically describe the operation of processes, tasks and activities [34]. The BPMN standard defines a set of notations that enable diagrams: (1) activity flow, (2) gateways (inclusive, exclusive or parallel), (3) inputs and outputs (documents required to perform tasks and/or documents obtained as a result of a task) and (4) participants involved. Appendix A presents the notation elements used in this document.

6.8 Game-Based Learning

Games that use technology are widely used to teach people conceptual knowledge and skills. There are different implementations of such games, such as serious games, gamification, and e-learning.

6.8.1 Serious Games

Serious games are games whose main objective is not fun or entertainment but the learning or practice of skills. In 1970, Clark Abt [35] defined this concept as follows in his book called "Serious Games" — "games that have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement. This does not mean that serious games are not, or should not be, entertaining".

6.8.2 Gamification

The concept of gamification was developed in 2003, and its use became widespread in 2010 through the work of multiple professionals. Gamification is formally defined as "the use of game elements and game design techniques in nongame contexts" [36]. When we talk about gamification, we tend to interpret it as a methodology where the purpose is to provide rewards to users to inspire personal and collective commitment, but this interpretation is very far from reality. Many authors maintain that the success of a gamified system or process lies in good design and adequate feedback, among many other factors. Other authors have supported this argument: for example, Kapp [3] stated, "Do not think of gamification as only the use of badges, rewards, and points. Instead, think of the engaging elements of why people play games—it is not just for the points—its [sic] for the sense of engagement, immediate feedback, and the success of striving against a challenge and overcoming it".

6.8.3 E-Learning

The term "e-Learning" comes from the abbreviation of "electronic learning". Khan [37] defined e-Learning as "a hypermedia instructional program that uses the attributes and resources of the Internet to create meaningful learning environments." That is, e-Learning refers to online teaching and learning through the Internet and technology.

6.8.4 Game Elements

Game elements are the components that make up a game to create an attractive experience for players. Werbach [36] described 25 such game elements. For the purpose of our study, we identify the relevant game elements are as follows:

- *Narrative:* Telling of a coherent story.
- *Progression:* Player growth and development.
- *Challenges:* Tasks that require an effort to perform.
- *Competition:* Players or groups that win or lose.
- *Rewards:* Benefits granted after a certain action.
- *Feedback:* Information about how the player is performing.
- *Avatars:* Visual representation of a player character.
- *Collections:* Set of items that can be accumulated.
- *Levels:* Steps defined in the progression of a player.
- *Leaderboard:* Visual representation of the player's progression with respect to others.
- *Points:* Numerical representation of the player's progression.
- *Achievements:* Accomplishment of defined objectives.
- *Teams:* Group of players who work together to achieve a common goal.

7 THE IMPACT OF TECHNOLOGY ON PEOPLE WITH AUTISM SPECTRUM DISORDER: A SYSTEMATIC LITERATURE REVIEW

Currently, autism spectrum disorder (ASD) affects a significant number of people who have difficulties with communication and socialization, which results in complexities for their learning. Studies have examined the use of technology and computer-based interventions to teach people with ASD language and social skills [2]. Specifically, students on the autism spectrum enjoy playing games, which provides a safe environment [3]. Thus, we reviewed the existing literature about the relationship between technology, games, user experience, accessibility, and the education and skill development of people with ASD. This section is organized as follows: Section 7.1 describes the research methodology, Section 7.2 analyzes the results obtained, and finally, Section 7.3 summarizes the work and presents our discussion.

7.1 Research Methodology

This systematic literature review was carried out following the process proposed by Kitchenham [38]. Kitchenham outlined three fundamental phases for conducting a review of the literature: (1) planning the review, which includes creating the research questions and reviewing the protocol; (2) conducting the review, which includes the review, the selection and quality of studies, data extraction and data synthesis; and (3) publicizing the results after the review. Next, we detail the process followed for this document.

7.1.1 Research Question

To cover every topic of interest in this systematic literature review, we formulated three research questions. These questions consider relevant and general aspects important for comprehending the concepts that we think are important for this study. These questions can be seen in Table 7.

Table 7. Research Questions for the Systematic Literature Review

ID	Research Question (RQ)
RQ1	In what way does the use of technology contribute to the education of people with autism spectrum disorder?
RQ2	Which user experience and accessibility elements/methods are considered when analyzing the impact of technology on people with autism spectrum disorder?
RQ3	Which game elements are considered when using gamification or serious games in the education of people with autism spectrum disorder?

7.1.2 Data Sources and Search Strategies

To conduct this systematic literature review, we searched for scientific papers on five databases: IEEE Xplore Digital Library, ACM Digital Library, Science Direct, Scopus, and Web of Science. For these sources, we considered only documents that were relevant in computer-related categories, such as technology, engineering and computer science, excluding categories related to medicine or chemistry. Additionally, we selected articles published during the last 10 years, between January 2009 and June 2019.

7.1.3 Article Selection

Once we chose the databases to search, we determined the specific search strings to find articles to answer the research questions and defined the exclusion and inclusion criteria to refine and filter the articles found.

7.1.3.1 Search Strings

We formulated the search strings based on the relevant topics to our systematic literature review. We determined a set of specific keywords to use in our queries, i.e., "Autism Spectrum Disorder", "Accessibility", "User Experience", "Gamification", "Serious Games", and "Game Elements" that would be useful to answer our research questions.

These strings were focused on finding studies that analyzed or experimented with the use of games with people with ASD, considering aspects such as the user experience, accessibility, and game elements. In Table 8, we present the specific search strings that were used in the selected databases.

Table 8. Search Strings

ID	Search Strings
SS1	("Autism spectrum disorders" OR ASD OR Autism) AND (Accessibility OR "User experience") AND ("game elements" OR gamification OR "Serious game" OR "game-based learning")
SS2	("Autism spectrum disorders" OR ASD OR Autism) AND (Accessibility OR "User experience")
SS3	("Autism spectrum disorders" OR ASD OR Autism) AND ("game elements" OR gamification OR "Serious game" OR "game-based learning")

7.1.3.2 Study Selection Criteria

To answer the research questions based on the selected articles and develop a general knowledge of the concepts that we were working with, we included the conditions listed Table 9.

Table 9. Inclusion Criteria

ID	Inclusion Criteria
IN1	Studies published over the last 10 years, between January 2009 and June 2019.
IN2	Journal articles and conference papers.
IN3	Studies with a focus on autism spectrum disorder.
IN4	Studies related to the usage of technology.
IN5	Studies performed in an educative context or focused on teaching.

The types of papers presented in Table 10 were excluded.

Table 10. Exclusion Criteria

ID	Exclusion Criteria
EX1	Studies with an exclusive medical focus or a focus on the diagnosis of autism spectrum disorder.
EX2	Studies that do not directly aim to help people with autism spectrum disorder but rather the people who work with them.

EX3	Studies that consider user experience and accessibility in contexts that do not involve the use of technology.

7.1.4 Document Selection

Applying the selection criteria, we gathered a total of 94 articles. Figure 1 shows the general process flow of the search and study selection for this review, detailing the inclusion and exclusion criteria applied in each step.

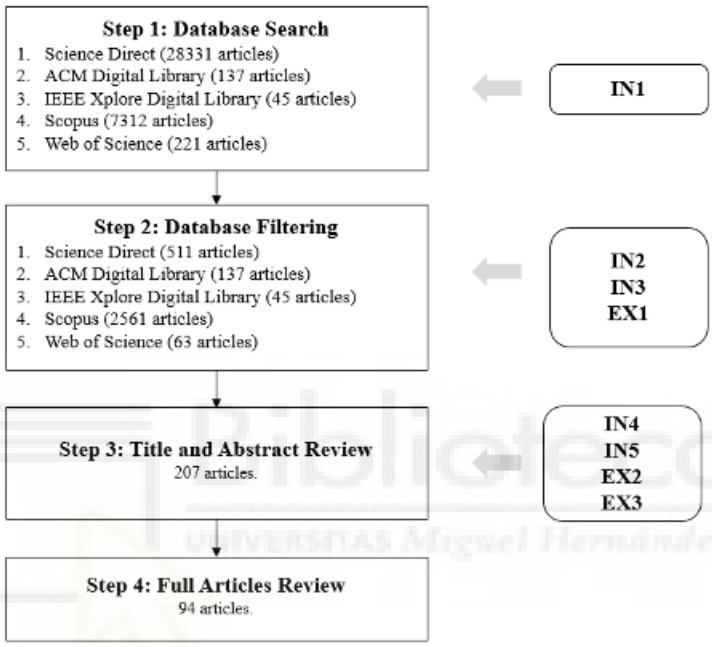

Figure 1. Flow Chart with the Results of the Article Selection Process

7.1.5 Data Synthesis

After the search, we extracted the information from each of the 94 studies, summarizing and tabulating the information based on different metrics, such as the year published, document type and paper category. In the following steps, we detail each of the metrics.

7.1.5.1 Year of Publication

As detailed above in the inclusion criteria section, we considered studies published during the last 10 years, between 2009 and 2019. As shown in Figure 2, we plotted the number of studies that were found that were published between 2009 and 2018, and we observed an increase in publication on this topic over this period. The studies found in 2019 are not presented in this plot because it would have been misleading to show incomplete data, as this review was finished in June 2019. Seventeen studies published in 2019 were found (almost equal to the number of publications in 2018), which led us to believe that this number will undoubtedly increase significantly during the remaining months of 2019.

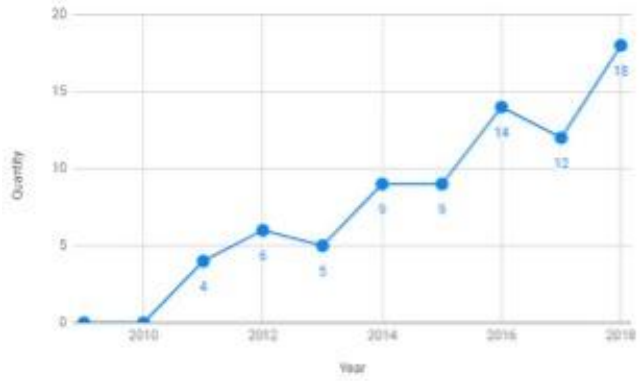

Figure 2. Year of Publication

7.1.5.2 Document Type

We analyzed the origin of the studies reviewed and determined whether they were conference proceedings or had been submitted to a scientific journal. Figure 3 shows a relative balance between the number of papers that were published as conference proceedings and in journals.

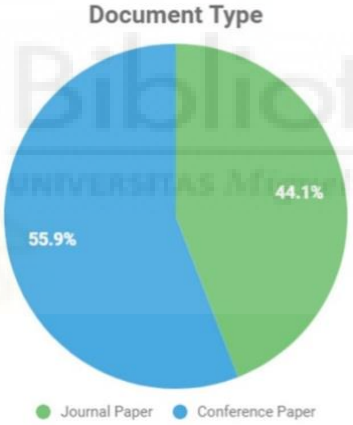

Figure 3. Document Type

7.1.5.3 Document Categories

The studies were categorized as follows:

- Review: An updated summary of a particular topic is provided.
- Case Study: A solution is given to a presented problem based on a tool, methodology, etc.
- Empirical Data: A context or situation is analyzed based on historical data.

Figure 4 shows that 74.5% of the studies analyzed were case studies. It is believed that this is because the researchers were focused mainly on conducting investigations and accomplishing their study objectives, such as teaching conceptual skills.

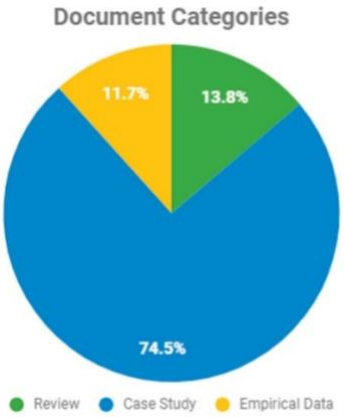

Figure 4. Document Categories

7.2 Results

After applying each of the filters described in the "Study Selection Criteria" section, as shown in Figure 1, a total of 94 studies were obtained. These studies were analyzed under different metrics, as seen in the "Data Synthesis" section. Based on our review of these studies, we now answer our research questions, considering those studies that are relevant to the specific context of each question.

7.2.1 **RQ1.** In what way does the use of technology contribute to the education of people with autism spectrum disorder?

As mentioned in the previous sections, ASD is a condition that is categorized as a disability due to the cognitive disorders that people with ASD face [39]. Several studies showed that most people with autism show a natural affinity for technology and a good disposition for using technology and learning through the use of computers [40]. This is because the environment and context that these experiences provide are predictable and structured, which helps people with ASD to maintain their routines and repetitive behaviors without affecting their comfort [41].

Several studies proposed the use of modern technologies to help teach skills to people with ASD. Some interesting examples of new technological approaches are the use of sensors, virtual reality, virtual agents, augmented reality, geolocation, and Kinect, as presented in the following studies. Wojciechowski et al. [41] developed a mobile application that, in conjunction with the use of Estimote Beacon sensors to identify objects, supports children with ASD in pronouncing new words and identifying their meanings. Lorenzo et al. [42] proposed an application that uses virtual reality and robots with cameras to detect children's emotions, adapt system interactions and thus develop social skills in students with autism spectrum disorder. Bernardini et al. [43] presented ECHOES, which is a serious game that focuses on the development of activities to promote social communication in children with ASD using an autonomous virtual agent that acts as a companion for children during their interactions with the system. Sorce et al. [44] developed an exploratory study to evaluate the effectiveness of the use of Kinect as a tool to allow people with ASD to explore works of art in a touchless virtual environment and assess whether this generates greater interest in them. Escobedo et al. [45] presented the Mobile Social Compass (MOSOCO) application,

which makes use of augmented reality through a mobile device camera to include game elements in real social situations with the aim of developing social skills in children with ASD. Silva et al. [46] presented a serious game that, through geolocation, virtual reality and augmented reality, creates a virtual environment with 3D virtual monsters positioned all over the world that aim to teach children with ASD relevant educational content, such as vocabulary.

In addition to examining the studies from a technological perspective, we categorized the 94 studies based on the following learning topics with the goal of understanding the contribution of technology to education for people with ASD in terms of the specific skills that they focus on teaching: Conceptual Skills (subtopics: Language, Money, Colors, Mathematics, Programming, and Science), Practical Skills (subtopics: Health, Daily Life, and Transportation), Social Skills (subtopics: Communication, Emotions, and Interpersonal Relationships) and General Skills (subtopic: General). Table 11 shows the percentage of studies for each of the topics and subtopics, and in the same way, Table F (available in appendix B) details each of the topics and subtopics according to which the articles were categorized. The results obtained after categorizing the studies are presented in the following sections.

Table 11. Learning Topic

Topic	Subtopic	Percentage by Subtopic	Percentage by Topic
Conceptual Skills	Language	14.89%	25.53%
	Money	1.06%	
	Colors	1.06%	
	Math	5.32%	
	Programming	2.13%	
	Science	1.06%	
Practical Skills	Healthcare	2.13%	8.51%
	Daily Living	3.19%	
	Transportation	3.19%	
Social Skills	Communication	9.57%	36.17%
	Emotions	12.77%	
	Interpersonal Relationships	13.83%	
General Skills	General	29.79%	29.79%

7.2.1.1 Conceptual Skills

First, 25.53% of the studies focused on analyzing and fostering skills within the range of Conceptual Skills. Studies in the Language subcategory focused on promoting the learning of expressions, thoughts and feelings through words. Examples of this include studies [39, 47]. Arciuli and Bailey [39] analyzed a small group of children with ASD that were literate using the ABRACADABRA application and observed significant improvements in reading accuracy in participants who interacted with the system but not in children who did not use the application. For the children who did not use the application, their lack of improvement was believed to be due to their lack of socialization aspects that children must exhibit when interacting with a teacher to develop reading ability. Khowaja et al. [47] developed a

prototype of a serious game for children with ASD to learn vocabulary. The effectiveness of the game was assessed through the comparison of children's performance at the beginning of the intervention, after the use of the prototype and 1–2 weeks after the use of the prototype, which enabled the researchers to track the improvement in the children's vocabulary.

Another subcategory of Conceptual Skills is the Money subcategory and only one study [6] was assigned to this subcategory. Caria et al. presented the design of a game that helps people with autism spectrum disorder acquire skills to help them understand the concept of money and its applications in real life, which was tested by obtaining positive and promising results.

In addition, like the Money subcategory, the Colors subcategory also included only one study, [48]. In this study, based on cognitive theories, Tũgbagül et al. developed a computer interface for students with ASD and mild mental disability that used their preferred colors and helped them maintain their concentration.

Additionally, the studies in the Math subcategory aimed to develop skills related to numbers. Examples of studies in this subcategory are [49, 50]. Tashnim et al. [49] developed the Play and Learn Number (PLaN) application, which teaches arithmetic and calculus to children who have ASD and helps children memorize and recognize numbers (in or not in sequences) through animated images. Muñoz-Soto [50] developed an application to support professionals in teaching functional mathematics and calculus to children with ASD. Through tests, it was possible to demonstrate that this application promotes the development of mathematical skills. However, it was suggested that the application should be tested by more users and in different institutions.

The Programming subcategory included studies that aimed to develop skills related to computational programming, for example, to design and order actions and commands. Only two studies were assigned to this subcategory, i.e., [51, 52]. Eiselt and Carter [51] planned and conducted programming classes through Scratch for children with ASD with the aim of developing their technical and social skills. Despite their efforts, no real evidence of an increase in students' social learning or behavior was found. However, while the students did not develop social skills as expected, the authors suggested that the students knew more about programming after the experiment since at the beginning, they did not have any notion of programming, but after the experiment, they could read and write processing programs. Schmidt and Beck [52] proposed a learning intervention based on digital games for young people with ASD to develop their social skills as they worked on teams to solve introductory computer programming problems with virtual and programmable robots. According to the authors, this intervention has the potential to help participants develop social skills, however, because this study was only concerned with the initial stages of development, there was no analysis of the data, so conclusions regarding cognitive skills could not be made with certainty.

Finally, the studies in the Science subcategory investigated and interpreted natural, social, and artificial phenomena. For this subcategory, we found only one study [53], in which Eder et al. developed a mobile game application as a complementary learning material to teach children with ASD parts of the human body. After the intervention, it was observed that the application was very useful for teaching and that the motivation levels of the participants increased significantly.

7.2.1.2 Practical Skills

Second, the Practical Skills category included only 8.51% of the identified studies and was subdivided into several subcategories. First, the Healthcare subcategory concerned teaching about the health care that people should have. An example of a study in this subcategory is [54]. De Urturi et al. [55] developed a system consisting of a set of serious games aimed at teaching first aid (such as what to do in certain situations and basic knowledge about medical care and medical specialties) to people with ASD. Because the application was still in development, only partial results were available, so to determine if these results were promising, the authors administered a simple questionnaire to the participants, as they obtained positive results, they decided to continue developing the project.

Another subcategory of Practical Skills is the Daily Living subcategory. The studies in this subcategory focused on building knowledge about the development of daily recurring activities, and examples are [56, 57]. Pérez-Fuster et al. [56] analyzed the impact of an intervention with digital technology (DT) compared to that of a treatment-as-usual (TAU) intervention on adults with ASD. The DT intervention sought to improve daily life skills, such as washing dishes and washing clothes. The results showed that the DT intervention significantly improved the daily life skills of the participants and was more effective than the TAU intervention. Fage et al. [57] presented a tablet application for children with ASD and children with intellectual disability (ID) that seeks to teach and develop routines in the classroom and verbal communication by directly involving teachers and assistants in schools. Children with ASD successfully adapted to the application, and their socioadaptive behaviors both in the classroom and related to verbal communication improved greatly. On the other hand, children with ID did not achieve autonomous use of the application, and they only had improvements in nonverbal classroom routines.

The final subcategory within the Practical Skills category is the Transportation subcategory. The studies in this category were concerned with teaching the necessary knowledge that individuals need to be able to transport themselves effectively. Some examples of this are found in [58, 14]. McKissick et al. [58] investigated the impact of a computer instruction package to teach map-reading skills to three elementary students with ASD. Very promising results were obtained for interventions that used technology with children with ASD, such as increased levels of learning and improved learning habits among students. De Los Rios [14] proposed a draft of a study to evaluate platforms and interfaces that help users transport themselves, such as Google Maps or Apple Maps with eye tracking. They compared these platforms and interfaces with a proposed system that would provide a more personalized environment that is adapted and accessible to the needs of people with ASD.

7.2.1.3 Social Skills

Third, the Social Skills category included 36.17% of the total resulting studies and was subdivided into three subcategories. The studies in the first subcategory, Communication, focused on the development of skills such as exchanging information between two or more individuals and examples from this subcategory are found in [59, 60]. Milne et al. [59] investigated the use of autonomous virtual humans (self-directed) to teach and facilitate the practice of basic social skills in greetings, conversation, listening, and shifts in conversation

to people with ASD. The results were positive, as users increased their knowledge and development of social skills. In addition, it has been indicated that this approach was well received by participants and caregivers. Ribeiro and Raposo [60] developed a game called ComFiM, which aims to encourage communication between people with severe degrees of autism. The game was evaluated based on the perceptions of the interlocutors of each player and the communication intentions observed between the players to collaborate with each other and the results showed that the application positively influenced the communication intentions of the players.

The Emotions subcategory included studies that examined the development of skills such as the identification of facial emotions. Some studies from this subcategory are [61, 62]. Romero [61] carried out a computer-based intervention to teach the recognition of emotions to students with communication and social skill deficits. All participants showed improvements when assessing and recognizing emotions on faces, but it was suggested that the effectiveness of the intervention should be tested in a larger population. Christinaki et al. [62] presented a serious game with a natural user interface (NUI) interaction that aims to teach young children with ASD to recognize and understand different facial emotions. The authors concluded that technological interventions with NUI improve the learning process and indicated that the emotional state of the players is directly related to their learning skills.

Additionally, the studies in the Interpersonal relationship's subcategory emphasized individuals' development of relationships. Some of the studies that were assigned to this subcategory are [63, 64]. Boyd et al. [63] described how collaborative assistance technologies, such as the Zody collaborative game, can be used to facilitate social relationships in children with ASD. They discussed how design can foster three levels of social relationship, i.e., membership, partnership, and friendship, even without the help of adults. The results indicate that collaborative technologies provide support for the development of social skills at different levels of intimacy between players without a mediator during the intervention. Hourcade et al. [64] conducted an intervention with multitouch tablets with children with ASD to promote their social skills and help them develop their creativity, alter their interests, and be able to understand emotions. The result of the intervention was that it increased pro-social behaviors, such as collaboration, coordination, and interest in social activities, in children with ASD.

7.2.1.4 General Skills

Finally, the General Skills category included 29.79% of the studies. As this category referred to a range of topics, we defined only one subcategory, the General subcategory; some example studies are [5, 65]. Backman et al. [5] investigated a method of evaluating children on the autism spectrum through computer games, which provide an objective, motivating, and safe evaluation of the participants. Although more research was recommended, the results showed that computer games have great potential in special education as an evaluation tool to clarify the difficulties associated with ASD. Hulusic and Pistoljevic [65] presented the initial development process of the LeFCA framework, which was used to teach children with ASD basic skills and concepts. LeFCA consists of four games that focus on developing basic skills (such as labeling, pointing and pairing in reference to visual and auditory stimuli) necessary for learning. Each of the participants was constantly motivated to play, and the

skills learned could be extrapolated to new media or environments without the need for any training.

After reviewing all the studies and classifying them based on their learning topics, as shown in Table 11, we can see that there are a few studies that used modern and/or complex technologies, such as virtual reality or sensors. These technological approaches are interesting examples of how this area is developing in innovative ways.

Notably, most of the studies focused on teaching Social Skills, such as Emotions (12.77%), Communication (9.57%), and Language (14.89%), which are the most important areas that people with ASD have difficulties with.

7.2.2 **RQ2.** Which user experience and accessibility elements/methods are considered when analyzing the impact of technology on people with autism spectrum disorder?

Although many of the studies suggested that accessibility and user experience are fundamental concepts for interventions with people who have ASD, these aspects were not treated with the importance that they should be.

Several of the studies that were reviewed from the pool of articles reported having used and/or considered user experience and/or accessibility, but most of these studies did not provide enough detail about the use of these concepts. Table G (available in appendix B) shows a total of 23 studies that in some way used and/or provided "detail" on the use of these concepts in their research. We can see that the most recurrent terms used in the studies were user experience, usability, and accessibility.

For instance, many of the studies claimed to have focused on accessibility when developing touchscreen applications, such as [48, 49, 64, 66, 67]. However, the authors' affirmations were not supported by empirical evidence or other details.

On the other hand, other studies such as [52, 14] proposed the evaluation of the usability and/or user experience of the systems in future works. De Los Rios [14] suggested evaluating the usability of the application based on eye tracking. Schmidt and Beck [52] proposed the use of eye-tracking, electroencephalogram (EEG) scanning, and focus group interviews to evaluate the usability of the system.

Studies such as [5, 53, 66, 68, 69] aimed to evaluate usability and user experience based on post-intervention questionnaires with users, as well as with the people around them (such as their teachers or parents). These studies worked with control and test groups of children with and without ASD. Few studies indicated the number of subjects involved in the experiments: 14 in [66], 11 in [53], and 30 in [5]. Forty teachers were also involved in the experiment described in [66]. In addition to the questionnaires, Santarosa and Conforto [69] and Backman et al. [5] carried out methods such as focus groups on their interventions to be able to evaluate the usability and user experience.

Additionally, in studies such as those by Khowaja and Salim [15] and Naziatul et al. [70], the proposed systems were evaluated based on heuristic evaluations. In these studies, the authors adapted the heuristics proposed by Nielsen [7] to the contexts of their interventions. In both cases, three experienced evaluators assessed the system usability.

In addition, in the study by Vallefuoco et al. [16], a usability user test was carried out with 10 children aged between 5 and 12 under the methodology proposed by Moreno Ger

[17] to evaluate the system, its usability, and the effectiveness of the customized elements developed to fulfill the objective of the study.

Finally, Caria et al. [6] worked with children with ASD between 16 and 22 years old, and Almeida et al. [71] worked with 40 children between 3 and 13 using the "System Usability Scale" (SUS) [18] to evaluate the usability of their applications.

As we can see, few studies provided details about how they used concepts such as usability, user experience and accessibility, how these concepts were evaluated, and what kind of users were involved in their experiments. We think that it is important to consider all these concepts when developing new solutions.

7.2.3 **RQ3.** Which game elements are considered when using gamification or serious games in the education of people with autism spectrum disorder?

Several of the identified studies described the use of game-based learning (mostly serious games), but they did not specify and/or provide details about the elements of the games that were used. However, a significant number of studies explicitly presented some game elements that allow these systems to be more attractive and engaging for users. In Table H (available in appendix B), we can see the game elements used in the studies, where the most frequent elements were points, levels, and rewards. Brief definitions of the game elements, as presented by Werbach [36], are presented in section 6.8.

For example, Vallefuoco et al. [16] analyzed a serious game that focused on improving math skills in children with ASD and for which one of the main elements was feedback. Likewise, Sorce et al. [44] used avatars in an application with Kinect to foster the interest of participants with ASD in digital representations of works of art, paintings, and sculptures. In addition, Romero [61] carried out a computer-based intervention with intrinsic rewards and points to teach the recognition of emotions. Similarly, Chen et al. [72] designed and developed a computer game with points and rewards to develop and evaluate emotional skills and conceptual comprehension skills (such as recognizing fruits) in children with autism spectrum disorder. Additionally, Harrold et al. [73] added to the concepts described above through the use of levels in CopyMe, a serious game for iPad, which provides children with ASD with a means to learn emotions through observation and mimics. In the same way, Sturm et al. [66] used stories in addition to rewards, points, and levels in a game with Kinect technology that aims to promote the recognition of emotions and encourage collaboration between people with ASD and their peers. Finally, Boyd et al. [63] described the use of Zody, as a collaborative assistance application, to teach social relations to children with ASD through the use of collaboration, points, levels, and rewards.

Most of the studies considered in this review did not explicitly identify which game elements they used in the development of their solutions. Even when they did, they did not give enough details on the effectiveness of the specific game elements. Although some authors claimed that their users were more engaged with the solutions they proposed, they did not provide empirical evidence to support such claims.

7.3 Summary and Discussion

Our systematic literature review focuses on analyzing the impact of technology on people with autism spectrum disorder based on research published during the last 10 years and

available on the relevant scientific databases. The analysis shows an increase in the papers published on this topic over the years, which indicates an increasing research interest in the area. Interestingly, the highest percentage of the papers presented are case studies (74%). The studies were categorized into four categories: Conceptual Skills, Practical Skills, Social Skills, and General Skills. Studies that focus on Social Skills are predominant (36.17%).

Regarding RQ1, we observe that new research has focused on supporting children with ASD by using technologies such as virtual reality, augmented reality, virtual agents, sensors, and geolocation through educational games. These studies emphasize teaching different skills to people with ASD in educational contexts, with a higher percentage of studies focusing on Social Skills (36.17%) than on Conceptual (25.53%) or Practical Skills (8.51%), which shows a need for more research and development of new solutions for teaching such important topics. Exploring these alternatives and expanding the technological solutions to teach skills to people with ASD seem to be promising research topics.

The results related to RQ2 show that several studies mention that aspects such as user experience, usability, and accessibility are crucial when working with people with ASD. However, these aspects are usually not considered or validated in detail. Although the use of new technologies, such as EEG scanning and eye tracking in [52], to evaluate the usability of their systems is indeed interesting, studies have shown that brain activity may be negatively correlated with the Asperger questionnaire [74] and may be weaker for individuals with ASD when observing other people's actions [75]. Future studies should be careful with the use of such technological approaches, as brain activity may be misleading when working with people with ASD, especially in tasks that require recognizing emotions from facial expressions or movements. We believe that user experience is important and that future studies should consider accessibility and usability tests to ensure positive experiences and comfort with the use of their solutions, as there is a lack of research that applies these concepts correctly and that provides details about the user groups that participate in interventions.

Regarding RQ3, we have observed in the literature that game elements are a good way to engage users with learning and enhance the effectiveness of teaching approaches for people with ASD, but our findings show that there is a lack of evidence about the effect of the use of game elements in gamification, e-learning, and serious game solutions. We believe that future studies should consider and validate the use of game elements. Werbach [36] highlighted that game elements are effective, have a positive relation with users' engagement, and have been widely used with promising results.

8 TECNOLOGY-BASED LEARNING FOR PEOPLE WITH AUTISM SPECTRUM DISORDER

Autism spectrum disorder (ASD) is a developmental disorder that affects people's communication and behavior [1]. Several studies have compiled the conditions presented by people with ASD and addressed these through different methods and/or systems. Most of the studies reviewed highlight the difficulties that people with ASD have regarding their social skills, specifically to maintain relationships and identify emotions, as well as their affinity with the use of technology. Studies such as Escobedo et al. [45], Milne et al. [59] and Sturm et al. [66] highlight the need to generalize these skills in daily life beyond an intervention with technology, so that these skills are applied not only during interventions. Other studies such as those by Christinaki et al. [62], Sturm et al. [66] and Lorenzo et al. [42] recommend the use of non-tactile interfaces to encourage interaction, since it is important to take into account the difficulties in the motor skills of the participants. In addition, studies such as Lorenzo et al. [42], Harrold et al. [73], Christinaki et al. [62], Hourcade et al. [64] and Romero [61] highlight the importance of interventions being predictable and structured, as these are better adapted to the characteristics of people with autism spectrum disorder. It is also important to note that many of these studies such as Ribeiro and Raposo [60], Christinaki et al. [62], Boyd et al. [63] and Bernardini et al. [43] are based on traditional interventions in people with ASD to design their technological solutions, such as the use of the Picture Exchange Communication System (PECS) [76], ABAB [77], SCERTS [78], TEACCH [79] intervention and social stories [80].

Taking into account the information collected through the review of 11 papers related to technology interventions to develop social skills in people with ASD, we have detailed: (1) the way in which these studies characterize the difficulties of people with ASD, (2) how these characteristics have been considered to design their technological solutions and (3) which are the results obtained in these studies, in order to determine design guidelines and a preliminary design for future technological intervention that applies what was learned in this research and that will be useful to determine and validate good practices that cover specific needs in people with ASD.

This section is organized as follows: Section 8.1 analyzes relevant related work; section 8.2 synthetizes some design guidelines for technological interventions for people with ASD; section 8.3 proposes a technological intervention focused on teaching social skills for people with ASD; finally, section 8.4 highlights conclusions and future work.

8.1 Related Work

In order to guide our work and determine our preliminary design for a new technological intervention to teach social skills to people with ASD, we reviewed 11 papers related to this topic of interest. These papers were selected based on a previous systematic literature review [4], where we classified them as technological interventions that aimed to teach social skills. For each of these studies, we identified how the authors characterize the difficulties of people with ASD, how they considered those characteristics to design their technological solutions, the results obtained in these studies, and also useful recommendations that can be helpful to

design our solution. The contributions of each of the 11 papers is detailed in the following paragraphs.

Ribeiro and Raposo [60] mention that “at about 50% of the people diagnosed with autism have problems in developing any kind of functional language”, and that most of their reviewed studies try to teach people with ASD to develop social skills such as vocabulary, but no communication skills between people with autism, and even more with people with severe autism. For this reason, they developed and validated the effectiveness of the ComFiM software, an educational and collaborative software that focuses on helping children with severe autism to promote communication between them.

ComFiM is based on the Picture Exchange Communication System (PECS) intervention [76], through which children can communicate by creating sentences or by selecting images that represent objects and actions, in order to develop essential actions to start a communication such as "I give" and "I want". The software has three levels of difficulty, where children must interact with a tablet to comply with what is indicated by the software through a screen in front of them. In the first level the player has to exchange messages with the tutor to perform some tasks, request or give an object to achieve the objectives. In the second level two children are participants in the interaction, and they should seek or give an object between them through messages in tablets, where the tutor fulfils the role of mediator. In the last level, players must fulfil each of the roles during interaction with the tablets and get to the goal in one movement (the tutor plays the role of mediator), thus requiring a greater degree of communication.

The authors indicate that the results obtained demonstrate that the software has allowed the development of communicational intentions in children such as gestures, short phrases, signs and looks among the players. The players during the course of time understood the role that the tutor was playing during each of the levels and sessions.

Boyd et al. [63] mention that people with ASD experience difficulties in developing social skills [81], which leads to social isolation [82]. Additionally, the authors mention that studies show that people with ASD are more susceptible to depression, indicating that this may occur due to lack of friendships [27]. For this reason, it is that an ABAB study [77] was conducted in order to evaluate how technology could increase the development of social skills in children, thus maximizing the impact of the results on the participants [83]. Subsequently, the authors have formed four dyads (giving a total of 8 children), in order to develop membership skills (the child's ability to participate in a group physically, contributing to the activities generated within it), partnership (the ability of how two people, with specific responsibilities, achieve a common goal mutually) and friendship (two individuals have mutual interests and mutual affinity). In order to develop these skills, they worked on sessions with children using Legos and with the application Zody, a collaborative game for iPad, which has four mini-games, each of these are interconnected through the plot of the game.

The results highlight that: (1) Membership can be strengthened with the careful design of the physical space provided to children, the small dimensions of the iPad generated a physical proximity between the players, and the assignment of well-defined roles encouraged the participation of participants. Although the authors mention that the lack of fulfilment of roles and that the physical space to interact, sometimes generated discomfort in some

participants. (2) Partnership is supported by the careful use of cooperative gestures [84], such as “serial gestures” which provides a structure where couples have the ability to take turns, and "simultaneous gestures", where players coordinate their actions on time. (3) Friendship is supported by the joys shared after "wins" and the empathy that occurs after a "loss" made the players generate understanding and friendship between them.

Bernardini et al [43], indicate that people with autism spectrum conditions (ASC) have three main areas of difficulty, known as the “triad of impairments” [85], which includes: (1) communication, which refers to problems with verbal and not verbal language, (2) social interaction, which refers to the problems to recognize and understand the emotions of other people, as well as to express their own emotions, and (3) patterns of restricted or repetitive behaviors, which exposes problems to adapt to new environments. For this reason, the authors present the design and implementation of a serious game called ECHOES, which focuses on helping young children with ASC to develop social communication skills.

ECHOES is based on recommendations of best practices of autism and the SCERTS framework [78], a framework that aims to identify the essential skills for successful social communication, from which they have taken into account supporting children in the subcomponents of communication: (i) Joint attention, ability to share attention, emotions and intentions with their peers, and (ii) Symbol use, ability to use objects, images, words or signs to represent things. The system is composed of a cognitive layer provided by FAtiMA [86] and a fragment of the Makaton language system [87], each of which forms a virtual agent called Andy. This agent plays different roles depending on the situations and/or actions that occur in the course of the child's interaction with the system, he acts as a partner and as a tutor.

After conducting a large-scale intervention, in which they deployed the application in five special needs schools, the authors documented children behavior in a pre-test with a tabletop game activity and using ECHOES. They also assessed the generalization of communication skills by conducting a final test with the tabletop activity. The authors found no significant evidence of transfer of skills, but saw evidence of children benefited from their exposure to ECHOES and its virtual agent Andy. The number of interactions from kids to Andy was significantly less than the ones done to their teachers at the beginning, but the difference disappeared at the end. Teachers highlight that ECHOES allowed children to show their communicative skills in a comfortable environment.

The authors highlight that having heterogeneity in the target populations can have a big impact on the intervention, as it makes difficult to create an environment suitable for all users, and that some degree of flexibility in the technology used is needed, as the intended use of a piece of technology such as a serious game will not necessarily be reflected in its actual use.

Christinaki et al. [62] highlight difficulties to understand and express emotions [88], the importance of early interventions [89], and the delay in fine motor skills which causes difficulties the interaction [25]. Considering this, they designed and tested a serious game to teach emotions identification to preschoolers with autism using a no-touch user interface (NUI) that reads hand gestures with Kinect. Their game is based on three levels: labelling emotions from images, recognizing emotions from descriptions and facial features, and recognizing causes of emotions in social stories [80]. For its design they incorporated

practices from traditional interventions for people with ASD such as one to one intensive play-based intervention from DIR/Floortime [90], visual support from PECS [76], positive reinforcement and rewards from ABA therapy [91], and a structural and predictable learning environment from TEACCH [79]. They considered the user needs for serious games for teaching people with ASD emotions [92]: repetition, matching instead of learning the features, lack of holistic face processing and deliberately incorrect selection. They also followed game design frameworks, identifying six relevant elements for game design for people with ASD: matching, recognition, observation, understanding, generalizing and mimicking.

After observing their experiments and conducting surveys, they concluded that NUI devices enhance game acceptance, game recognition and player involvement and participation, the player's emotional state is affecting its learning abilities in such a way that sometimes it makes the learning process impossible, and that minor changes in where the game is played affect dramatically the game acknowledgement, game acceptance, and game interaction but have a small or no effect on the NUI device avatar acknowledgement.

Sturm and et al. [66] mention the importance of computerized education, which can be more motivating than in-person education for autistic people [93] as it is well-aligned with the processing styles of many autistic people [94]. The authors highlight the relevance of generalizing skills learned from a computer interaction to in-person interactions. Whyte et al. [95] speculated that problems in generalization may be attributable to flaws in game design, and recommended the use of hybrid computer and in-person interactive opportunities. Taking in account the generalization of skills, they included people with ASD in a participatory design process, as this is engaging and promote generalization [96], of ConnectingTK, a serious game that focuses on teaching emotion recognition of complex emotions through collaboration between players and using body movements through Kinect. In this game, two players stand side by side using hand gestures to move the pieces of a puzzle, which shows an emotional face that is related to a relevant social situation.

After the participatory design process and applying surveys, their results showed that students have difficulties to recognize complex emotions, users show better results when paired with non-ASD users, and that participatory design was well received, as the students felt involved, and they recommend their experience. The authors also recommend improving the communication channels in their participatory design, and provide more engagement in their solution using shared discoveries, not imposed by the game.

Lorenzo et al. [42] describes some characteristics of people with ASD, such as their emotional incapacity to maintain empathic relationships and to identify emotions [97], and that they have a tendency towards visual and structured thinking [24]. Baron-Cohen [98] indicate some aspects that characterize the difficulties related to the empathic capacities of people with ASD, such as minor joint attention frequency, less imaginary games and more activities with clear rules, a reduction in intuitive comprehension, Impairment in the capacity to understand the meaning of things and/or predict other people's behavior, a high capacity to pay attention to details, and a significant retardation in the perception and comprehension of emotions and as a consequence, an inappropriate response to other people's emotions. Considering this, the authors developed an IVRS (Immersive Virtual Reality Systems) to stimulate the notably visual cognitive processing that characterizes students with ASD for

the purpose of improving the student's emotional skills. IVRS allows repetition and systematization, which can lead to a reduction of this emotional deficit. In this application they used the IVRS to recreate situations, in the form of social stories [80], which allows the recognition of expression and emotions as well as the training of appropriate emotional behavior. Their experiment consisted in two phases: (1) Identification of the situation and the emotions, where the evaluator explains the social situation and asks the child about the components of the situation and about the different characters' emotions, and (2) implementation of the emotional script, where there is an established common emotional script for all the social stories, in which the users need to follow and select appropriate behaviors. They also included a computer vision system to follow and assess the user's emotion automatically. The results of their experiments showed that training helps the child to adapt to the virtual environment and improves the identification in the IVRS more than in the traditional VR, students that carry out the social stories in the immersive environment show significant improvements related to the emotional behaviors and the compliance with the guidelines, and users reduce their inadequate emotional behaviors in the IVRS, according to the automatic computer vision assessment. They also assessed the generalization of the skills through surveys directed to the teachers of the children, where they noted improvement in their social skills in the school environment.

Escobedo et al. [45] characterize people with ASD as people with social skills impairments [85], that struggle with making eye contact when interacting with others, and are more willing to initiate play and to interact appropriately when using entertainment-based assistive technologies, as it also helps them to maintain concentration. They also highlight the need of generalizing skills beyond the classroom. Considering this, they developed MOSOCO, a mobile assistive application that uses augmented reality and the visual supports of a validated curriculum, the Social Compass (A behavioral and educational curriculum), to help children with autism practice social skills in real-life situations. The minimal social skills required for social interaction are addressed by six lessons from the Social Compass curriculum: eye contact, space and proximity, start interaction, asking questions, sharing interests, and finishing interaction. Using augmented reality MOSOCO encourages them to make eye contact, maintain appropriate spatial boundaries, reply to conversation initiators, share interests with partners, disengage appropriately at the end of an interaction, and identify potential communication partners.

Students received MOSOCO positively, finding it useful, fun, and helpful. The application increases quantity and quality of social interactions, reduces social and behavioral missteps, and enables the integration of children with autism in social groups of neurotypical children, which interacted physically more when using the application. The authors recommend to have more game-like interactions, as they were engaging, and also use context-aware tools, that can recognize interaction contexts and react accordingly.

Hourcade et al. [64] characterizes children with ASD, as people that are unlikely to live independently when reaching adulthood, have impairments in social interactions and communication [85] and show strong interest in computers. They favor local over holistic processing [99]. Considering this, they developed computer supported activities to enhance the social skills of children with ASD with an emphasis on collaboration, coordination, creativity, compromising one's interests with the interests of others, and understanding

emotions, enabling them to better collaborate, be creative, express themselves, compromise their interests, and understand emotions. For this, they used multi-touch tablets as a platform to support face-to-face activities. They considered their applications to be mistake-free, not showing errors, or system states, in order to reduce frustration. They used four different applications: (1) Drawing, where they used stylus to draw and express themselves, how they feel, and share with others. They also did collaborative interventions related to storytelling through drawings. (2) Music Authoring, where they created music in a harp-like interface. This allowed them to create something to share, and have fun with something out of their interests. They also included a collaborative activity where they passed the tablet to create together. (3) Untangle: a puzzle to encourage communication, collaboration, coordination and visuospatial thinking. (4) Photogoo: which enables children to distort images by dragging their fingers on the screen, allowing them to modify faces of cartoons to express emotions. The users improved their prosocial behaviors such as collaboration, coordination, augmented appreciation of social activities, and provided new forms of expressions, which also helped nonverbal children to express their thoughts and emotions.

The authors recommend using a toolbox of activities instead of only one computer intervention, that users should reach a level of personal comfort on a new activity before doing it in groups, and create safe and predictable environments to help the comfort of the children.

Milne et al. [59] characterize children with autism as people with difficulties with social skills for which is challenging understanding nonverbal cues and social behaviors [100], have affinity with technology [101], and have difficulties when generalizing skills to real-world contexts [26]. Considering those difficulties, they used autonomous virtual humans to teach and facilitate practice of basic social skills in the areas of greeting, conversation, listening and turn taking. Those virtual human characters guide the learner in tasks and social scenarios, together with a teacher, a peer with strong social skills and a peer developing social skills. Being a technology-based approach, this benefits from immediate feedback and prompting, allowing the students to work at their own pace, reducing frustration. The solution also includes a three-tiered extrinsic reward system, to engage the participants. The authors recommend that assessment should be integrated in the overall learning, rather than being a separate activity, and should be used to continually inform and adjust activities presented to learners [102], and also highlighted that rewards and punishment only has a small influence in educational outcomes [103], but feedback with helpful suggestions can be beneficial for learners.

In [61], Romero determines that people with ASD have difficulties interpreting and or predicting emotions of others, which affects their social competence. Social competence can have a positive effect on the quality of people's life [104], including maintaining mutually satisfying relationships, and increasing the ability to hold to a job [105]. Poor Theory of Mind abilities have been linked to difficulties interacting with others, especially in emotion recognition [106] social competence [107] and anxiety in social situations [108]. The Ability to attribute mental states to others is important for people with ASD and requires awareness and attention to facial expressions [109]. Facial expressions provide important clues to an individual’s mental state.

The authors considered the difficulties related to emotion recognition to develop a computer intervention program, “The Transporters”. This program consists of 15 episodes, each focused on an emotion or mental state: happy, sad, angry, afraid, disgusted, surprised, excited, tired, unfriendly, kind, sorry, proud, jealous, joking, and ashamed, where users can learn to understand each expression with real life characters grafted onto vehicles that are presented with limited movement, to be predictable. The program also includes quizzes related to each episode.

The authors performed pre-assessments of the emotion recognition elements, and then the users were presented with scenarios to play, that consider the interests of the child, to increase the likelihood that they would like and watch the scenario to play out. They used narrators in order to not distract the users from the emotions of the characters. In the interventions they conducted a quiz which had three types of questions: (a) matching faces with faces (match the two characters that are feeling the same); (b) matching faces to an emotion (identify the face that portrays a specific emotion); (c) matching situations with faces (identify the correct emotion that might be displayed in a given situation).

After their interventions, the authors observed changes in the ability to process information from local to global processing of faces, and improvements of the ability to attribute mental states to others. They also showed improvement in emotion recognition in faces, generalized their knowledge and maintained the gains after the intervention.

Harrold et al. [73] considered their intervention, CopyMe, an early intervention for people with ASD, which is crucial to ease their struggle. As stated in other studies, people with ASD tend to like the use of technology, as it represents a structured and predictable environment to learn. CopyMe is an iPad serious game to learn emotions through observation and mimicry which combines automatic facial expression recognition technologies with real-time feedback for players performances. The players observe a photo of a human face, then attempt to copy it using the tablet camera, and a score is calculated to record successes without penalties for failed attempts, aiming to reinforce desired behaviors without causing stress. They tested their interventions with six children, 2 with ASD, aged 8 to 10, having 5 minutes of playtime and then 5 minutes of post-session interview, where they were asked 13 questions about the usefulness of the game to teach emotions. All the participants liked the use of iPad, and the ASD affected participants demonstrated enjoyment of the predictability of the game repetition, showing high levels of motivation and performance during gameplay.

The authors recommend using simple and uncluttered interfaces, as it's helpful to engage children with ASD, having scenarios to associate emotions and step-by-step or animated approach to demonstrate how to form an expression. They also highlight the importance of having visual rewards and achievement systems to enhance the experience and engage children for longer periods of time.

The reviewed studies present common ideas, such as having predictable and structured environments, or using tablets or Kinect to promote interactions. As the selected studies were focused on teaching social skills, most of the presented activities were related to emotion recognition, as this is a fundamental skill for social interactions. The authors also provided insights, good practices and lessons learned, which we have compiled as a set of design guidelines that consider the most relevant design elements that we discovered during the review phase.

8.2 Design Guidelines for Technological Interventions for People with ASD

After reviewing the 11 studies, identifying how they characterize difficulties of people with ASD, how they designed their technological solutions considering those difficulties and their results, we propose a structure and preliminary design for a future technological intervention to teach social skills to people with ASD. For this we propose a set of design guidelines that considers techniques successfully tested and applied in the reviewed interventions, lessons learned and good practices that the authors recommend, such as (1) having a structured and predictable learning environment, (2) provide ways to generalize skills to daily life, (3) consider different learning dynamics: individual and collaborative, (4) set engaging activity cycles through game elements: progress, feedback, rewards, (5) managing error, (6) have a variety of activity types, (7) using no-touch and technological-real hybrid interfaces. Using these elements, we defined a technological intervention based on PECS [76] which we aim to implement and validate in future works. In this section we first detail each of the 7 design guidelines considered, and then we describe our technological intervention proposal.

8.2.1 Structured and Predictable Learning Environment

Considering that according to DSM-5 [1], people with ASD have restricted and repetitive patterns of verbal and nonverbal behavior, interests, or activities, in order to design interventions that cover needs in individuals with ASD, it is necessary a certain accommodation to these modes of functioning. Thus, it is important that these interventions offer a structured and predictable learning environment [42, 61, 62, 64, 73]. As Lorenzo et al. [42] and Ribeiro and Raposo [60] indicate, it becomes relevant that people with ASD who participate in different types of activities are presented with the instructions in a clear, short, concise, simple and explicit way.

In this sense, incorporating technology can help an intervention with greater structuring and predictability, also increasing the attention, interest, engagement, and enjoyment [64] of individuals with ASD, since they exhibit high technology usage patterns and report a significant affinity for technology [101, 110].

In regard to socialization, as people with ASD find real social interactions to be stressful and intimidating because of their unpredictability [43], as well as initially frightening, challenging, and even undesirable, Hourcade et al. [64] explain that paired with technology, the process of enhancing social skills, might be a reward within itself. In order to improve the quality of social bonding, technology may be enough of an incentive, being also able to provide instead of the usual open-endedness of social relations, that inconvenience individuals with ASD, a more structured narrative for their interaction patterns [64].

8.2.2 Generalization to Daily Life

The patterns of restricted or repetitive behaviors that characterize people with ASD leads to problems with adapting to novel environments [1]. Considering that the transfer and generalization of skills learned from virtual or computerized contexts to the real world [42, 59, 66, 26] and from classroom learning to novel contexts and real-life situations [45, 111] are a known difficulty and a significant limitation for these people [61], these aspects are

widely recognized issues in relation to interventions of any kind [59], that should be addressed from the design of the interventions.

In order to apply and transfer what individuals with ASD learn to daily situations outside the context of the interventions and to natural environments that involve family members and peers [45, 59], it is necessary to design situations with elements known by the students, which are as real as possible [42]. In addition, it is important to consider that facing to the practice of several behaviors or aspects to be taught or improved in different contexts, can help people with ASD to extrapolate and generalize the skills learned to a wider range of capacities, situations and contexts [43].

8.2.3 Learning Dynamics: Individual and Collaborative

As recommended by Ribeiro and Raposo [60], we considered to use a two-phase model, where the student could start learning in an individual intervention where the participant can get acquainted with the activity and have its own progress, to later move towards a group activity. It is important to note that this first phase a tutor will be supporting the process. The second phase could include group activities, which can be based on improving over three social phases, membership, partnership and friendship as stated in [63]. In membership, the participant who wants to enter the group must perform a symbolic act as an entry, such as sitting at the same table. In this form of organization there is no clear division of duties or responsibilities. Partnership involves two people who have specific responsibilities to achieve a mutual objective, and the responsibility is divided, and the individuals are interdependent in relation to the performance of the activity. Finally, friendships are based on sharing mutual interests and that often involves having fun together, which can lead to lasting relationships. In addition to these forms of organization of the group activity, there are additional elements that are important to consider, such as symmetry, parallelism, proxemic distance, additivity, identity awareness and the number of users [63].

In the case of Symmetry, the activities to be carried out are considered equivalent in effort and importance. The above can be obtained by having each participant perform the same activity or by making them equivalent in difficulty.

With regard to Parallelism, this can be done in two main ways: making the participants carry out the activity in the same period of time or in a chain, where an activity begins, and at the end of it, the next participant continues. This would imply that the participants were obligated to take and respect turns if they want to achieve the objectives.

On the other hand, the Proxemic Distance between the participants is an element that must be taken into account. For this we must consider both the construction of the software and the means where it will be installed. An example of this is, if a small tablet is used for more than one person to interact simultaneously, they may be forced to get too close to each other to be able to access the activity at the same time. Otherwise, if proximity it is not wanted, a larger architecture can be used, or the use of the Internet can be allowed, so that people can participate while not being in the same physical place.

In addition, Additivity, as a key element, implies that when more than one participant performs a specific action, a synergy is generated in the result. This could mean that a certain number of participants perform an action such as pressing a button that would unlock or give access to a new item or activity. In a similar range is Identity Awareness, however, in this

case the participants have different roles and must work together to obtain a result that would otherwise be impossible.

Finally, the number of users and number of devices would determine the complexity in learning and the level of organization that might need it to perform it. The management of these structural elements could define which skills or abilities are worked within the device, for example, taking turns, teamwork, tolerance, empathy among others.

8.2.4 Engagement Through Activity Cycles and Game Elements

Studies such as Boyd and Kapp [3, 63] indicate that games provide a proper environment to develop social skills in people with ASD. Additionally, studies such as Werbach's [36] indicate that the use of game elements in non-game contexts can generate an attractive and motivating environment for users. Concepts such as motivation, rewards, feedback and progress are interesting to consider when designing game interventions for people with ASD.

Motivation encourages users to achieve objectives and develop expected behaviors. This motivation can be extrinsic and intrinsic. Extrinsic motivation is based on the theory of behaviorism, which indicates that humans and animals respond to external stimuli in predictable ways [112], so these types of stimuli encourage people to achieve things. On the other hand, intrinsic motivation is based on the theory of self-determination [113] and indicates that humans are inherently pro-active, with a desire to develop.

Rewards can be powerful incentives for continued participation [63]. However, offering a high number of external rewards such as real-world prizes or benefits, produces a "Displacement Effect" [114]: an increase in extrinsic motivation thus dissipating intrinsic, so it is important to have a balance when applying these concepts.

Accurate and helpful feedback can be beneficial when working with people with ASD [59]. Feedback can come from different places such as progress towards an objective, from a peer, or as a response to an action within the context [36], thus helping to generate autonomy within the system, generate intrinsic motivation and originate possible friendships between people with ASD. Feedback is a key element for games to be effective and motivating. The use of concepts such as feedback, motivation and rewards generate what is known as the activity cycle, important to generate a greater commitment in users. The activity cycle indicates how motivation is capable of generating an action, which receives immediate feedback through rewards or points, and then motivates the user to perform more actions [36].

It is important to consider a progression system in the design, as activity cycles do not capture user progression. Progression can be designed as progression stairs [36], which consider the use of levels and difficulty scaling. Having a way for the users to visualize the progress during the interaction is important to increase interest in the system, engage and motivate users, especially when considering that people with ASD have the ability to process and search visually [115, 116]. Establishing challenges that eventually increase in difficulty, followed by periods of rest or consolidation are relevant to consider.

8.2.5 Error Managing

People with ASD tend to be more susceptible to depression and frustration [27]. Many of the people with autism spectrum disorder get frustrated at not being able to express their

emotions, thoughts and needs. Studies such as Hourcade et al. [64] recommend that systems should be free of errors, error messages, incorrect answers and unclear instructions, so as not to cause frustration in people with ASD.

Having feedback focused on constructive suggestions, such as the use of positive and concise expressions such as "oh, you were wrong, try another card", or facial expressions and obvious gestures for people with ASD [43], encourages the search for solutions, thus regulating frustration.

8.2.6 Mixed Activities

People with ASD have traditionally demonstrated a certain ease and ability to interact with computers, an aspect that can open doors to new treatments thanks to the application of technology [117], Regarding the development of activities, it is necessary to consider that many of the distractors or everyday elements that can disorient people with autism, disappear when they enter a controlled environment, such as therapy. In addition, when using a digital platform, the adaptation of the various levels or degrees of difficulty in the activities is facilitated when considering the user's own characteristics, since the tasks can be adjusted to the level of progress or development that the person possesses. Particular learning rhythms could be stimulated by accompanying through a higher rate of individualization, in order to promote active learning, with flexibility and adaptability [118].

With regard to diversity in activities, there is a need to create a platform that allows a balance between different guided activities and free activities based on exploration and on spontaneity [119]. As for the possibility of repeating levels or activities, it could be counterproductive if they are identical, since it could encourage memorization. Some students may also use repetition as a way to avoid working: play past levels instead of solving the current problem or move on [120]. That is why presenting alternative forms or proposing a system that only promotes progress, over repetition, could be a favorable alternative.

8.2.7 No-touch and Hybrid Interfaces

Studies such as Boyd et al. [63] mention that the use of tablets provides an effective and efficient platform when it comes to developing social skills in people with ASD, since these are portable, low-cost, generate a fun environment and do not require human mediators. The same study [63] cites that touch screens and/or interactive surfaces "allow face-to-face interaction and multiple simultaneous inputs from individuals acting independently or as part of a group" [84].

However, studies such as Strum et al. [66] highlight the use of technologies such as Kinect, as this provides tools to recreate social interactions that arise in the real world, where people generally must interact with each other using body movements, thus generalizing what has been learned to everyday life. Also, studies such as Christinaki et al. [62] highlight the delay in fine motor skills in people with ASD, causing difficulties to grab and manipulate objects [25], such as interacting with a mouse. Additionally, in [62] it is mentioned that the use of non-tactile systems controlled by hand gestures allows users to focus on learning and not be distracted by the use of complex interaction devices for them. It is important to consider the use of no-touch interfaces and hybrids between technological and not-

technological interaction interfaces in the solution design, as they can provide an extra layer of accessibility and encourages the generalization of skills.

8.3 Intervention Proposal

Considering the design elements detailed in section 3, we propose a preliminary design for a technological intervention focused on teaching social skills for people with ASD. The core of our proposed hybrid intervention will be based on the traditional intervention PECS [76], and will include the recommendations detailed in the previous section. We aim to implement and validate this proposal in future works.

Within the communicative difficulty of people with ASD, an intervention method for the language area is through augmentative - alternative communication systems (AAC) [121]. These communication systems can be sign language, voice generating devices or exchange-based communication [122]. For example, one of the most commonly used ACC is PECS, a method where they are taught to exchange symbols or images for specific elements instead of pointing them out on a communication monitor [123]. The use of these symbols is intended to clarify and accelerate communication without texts or words [124], increasing understanding by eliminating dependence on abstract words and concepts such as physical or spatial objects [125]. Studies have been carried out to analyze this type of behavior and it has been concluded that people with autism have superior visuospatial processing, activating more brain areas when listening to everyday language [125]. Another type of investigation revealed that people with autism have difficulties in following instructions, which is enhanced by the use of images. [126, 127].

PECS it is widely known and used for learning activities for people with ASD, and could be improved through the use of a hybrid technological implementation to support its use, such as integrating a tablet to display images and gamification-elements with physical objects like the image cards used in the traditional PECS intervention. An interesting approach to achieve this could be the use of NFC cards as physical objects to interact with the tablet software. These cards can include images related to emotion-recognition or other objects that are relevant to teach social skills in general.

Creating a hybrid intervention between the software application and physical interactive cards, will allow us to include all the design guidelines discussed in this study, such as different learning dynamics and types of activities, gamified progression and rewards, and error managing.

8.4 Summary and Discussion

We have reviewed 11 papers in which technological interventions have been created to develop social skills in people with ASD. After identifying how the authors characterize difficulties of people with ASD, how they are addressing these difficulties with their interventions and which were the results obtained, we have compiled and proposed design guidelines, considering common approaches, author recommendations and lessons learned in the reviewed studies. Our set of 7 design guidelines are expected to be a solid starting point for the design of new technological interventions to teach social skills to people with ASD.

Technological approaches to teach skills for people with ASD are a promising field to explore, and setting up design guidelines can be relevant to facilitate the development of new interventions, thus also helping the skill learning for people with ASD.

Considering our design guidelines, we proposed the base structure for a new technological intervention based on the PECS traditional intervention, which we aim to implement and validate in future works, helping us to also validate the guidelines established.

9 PROCESS TO CREATE THE METHODOLOGY

We have followed a seven-stage process to create the proposed methodology. It has been iterated twice in order to validate and refine the methodology (see Figure 5).

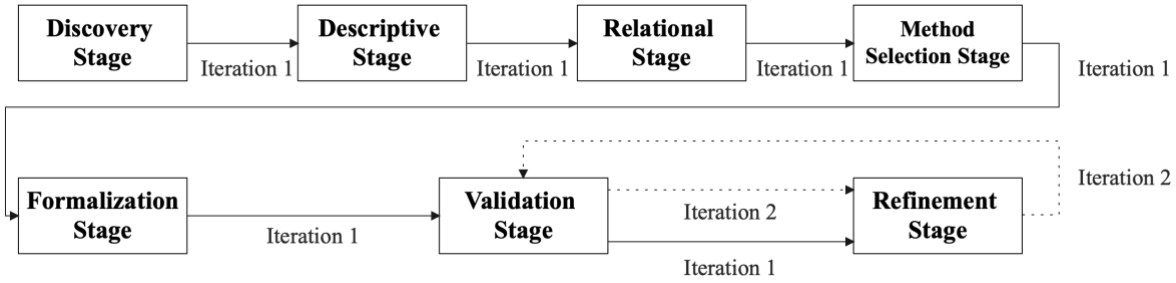

Figure 5. Methodology Development Process Outline

9.1 First Iteration

For the first iteration, all the stages have been executed (see Figure 5):

- **Discovery Stage**: We carried out a systematic literature review to know the impact that technology has on people with ASD and how UX/Usability has been evaluated in the proposed systems [4]. The studies indicate that they have evaluated their proposals through various evaluation methods, but these methods have not been particularized considering the characteristics of people with ASD [4].
- **Descriptive Stage**: We compiled the information found in the literature on the following topics: (1) characteristics, affinities and needs in people with ASD, (2) recommendations and comments from the authors on UX/Usability evaluations in systems, products or services used by people with ASD, and (3) UX attributes/facets/factors appropriate to the context of our research.
- **Relational Stage**: During the research carried out, a set of UX attributes/facets/factors focused on people with ASD has not been found, so by relating the information collected in the descriptive stage, we have proposed a set of nine UX factors for people with ASD [11].
- **Method Selection Stage**: We have selected a set of six evaluation methods suitable for people with ASD found in the discovery stage and on the website www.allaboutux.org [128]. Evaluation methods (special emphasis on user tests) based on individual and group questionnaires, focused on emotions and easy expressions, have been excluded.
- **Formalization Stage**: With the results obtained in the previous stages, we have formalized and published a preliminary proposal of the methodology to evaluate UX for people with ASD [9]. The proposal considers planning, execution, and result analysis stages.
- **Validation Stage**: We have validated the preliminary proposal of the methodology [9] through the opinions of three UX expert researchers. The experts

have been asked about elements to add, modify, or eliminate to improve the methodology.

- **Refinement Stage***:* We refined the preliminary proposal of the methodology [9] based on the results obtained in the previous stage. All comments and recommendations have been considered to improve the methodology.

9.2 Second Iteration

We have carried out a second iteration, which consisted of executing the validation and refinement stages again (see Figure 5):

- **Validation Stage**: An expert judgment evaluation was carried out with 22 experts with knowledge in UX/Usability, ASD and/or both. The expert judgment evaluation focused on gathering comments and suggestions of the experts about the stages, substages and the methodology in general (see section 13).
- **Refinement Stage**: We have refined the methodology based on the comments and suggestions obtained in the expert judgment evaluation. The corresponding changes have been made after analyzing the comments and suggestions of the experts (see section 13), resulting in the final version of the methodology proposed in section 12.

10 USER EXPERIENCE FACTORS FOR PEOPLE WITH AUTISM SPECTRUM DISORDER

Several studies have developed and evaluated User eXperience (UX) in systems for people with ASD. These studies have focused on evaluating UX using various methods available in the literature such as focus groups, eye tracking, heuristics evaluation, and questionnaires after interactions with the systems, which do not present sufficient details for evaluations. There is a lack of empirical evidence in their research, as described by a previous systematic literature review [4].

In a second literature review [8], we found studies that propose different characteristics to consider when working with people with ASD as well as others that propose guidelines and/or recommendations for designing systems for these users. However, no study presents particular UX factors for people with ASD. We think that it is important to consider a set of specific UX factors that could facilitate UX evaluation and design.

This is why, taking into account the works previously found in the literature [4, 8] as well as new studies added for this research, we have designed a proposal of nine UX factors for people with ASD based on two approaches: (1) the characteristics, affinities, and needs of people with ASD, and (2) design guidelines and/or recommendations provided by studies focused on technological systems for people with ASD and/or interventions with these users. The nine proposed UX factors are focused on evaluating systems de-signed for adults with ASD of severity level 1, "Requiring support", as defined by the DSM-5 [1].

This section is organized as follows: Section 10.1 describes relevant related work; Section 10.2 introduces and describes the process used to create a preliminary proposal of UX factors for people with ASD; Section 10.3 presents the final set of nine UX factors for people with ASD; and Section 10.4 presents a summary and discussion.

10.1 Related Work

In a previous study [4], we analyzed the impact that technology has on people with ASD. One of the research questions answered in this research was "Which user experience and accessibility elements/methods are considered when analyzing the impact of technology on people with autism spectrum disorder?". We found a lack of empirical evidence and details from studies evaluating user experience and/or usability in systems designed for people with ASD.

After the systematic literature review carried out previously [4] and a review of the literature at present, we found studies that have evaluated the user experience and/or usability in systems designed for people with ASD. Some studies [5, 52, 69] mention having carried out focus groups, and other studies [14, 52, 129] propose the use of eye tracking. In [5, 53, 66, 68, 69, 130], the authors distribute questionnaires to users after having interacted with the systems, and in the same way, studies such as [6, 71, 131] evaluate the usability of systems through the use of the "System Usability Scale" (SUS) [18] or SUS-ASD [132].

Vallefuoco et al. [16] evaluated the usability of their software system based on Moreno Ger's methodology [17], which facilitates usability tests for serious games. Furthermore, studies [133, 134, 135] claim to have evaluated the usability of their systems designed for people with ASD based on an analysis of observations, through the collection

of comments, and/or with the help of experts in the domain of people with ASD. On the other hand, studies such as Naziatul et al. [70] propose evaluating the usability of systems for people with ASD through adaptations of the Nielsen heuristics [7]. Furthermore, studies such as [48, 49, 64, 66, 67] claim to have developed systems for people with ASD with a focus on accessibility given by the use of touch screens.

These studies do not present empirical evidence or details that formalize the process of evaluating the user experience with systems designed for people with ASD. Additionally, no studies formally specify the attributes/factors/aspects of UX for systems de-signed for people with ASD, which we believe would provide a basis for formalizing the evaluation process. However, studies do identify the creation and/or use of design guidelines that characterize people with ASD as a means to develop systems for said people in different contexts, which can be a starting point for creating UX factors tailored to people with ASD. Below are studies that define design guidelines based on the characteristics of people with ASD.

10.1.1 Technology-Related Research

As described in [4], some studies have focused on proposing design guidelines for technological systems for people with ASD based on reviews of the literature and the characteristics of the users. Research has focused on creating/proposing design guidelines focused on tactile and nontactile systems for serious games and/or systems designed to develop learning skills in people with ASD.

In our previous study [8], a total of eleven studies focused on developing social skills were analyzed to propose design guidelines and best practices for future technological interventions in people with ASD. Here, a total of seven design guidelines are proposed: (1) structured and predictable learning environments; (2) generalization to daily life, (3) learning dynamics: individual and collaborative; (4) engagement through activity cycles and game elements; (5) error management; (6) mixed activities; and (7) no-touch and hybrid interfaces.

In [136], a set of design guidelines for motion-based touchless interaction for medium-low functioning children with ASD are proposed. These design guidelines were developed based on empirical studies and collaborations with therapeutic centers. This set of design guidelines has been classified into two categories, the first of which is related to general aspects of interface/interaction and the second of which considers specific aspects according to the expected learning objectives, which in turn have been classified into the motor, cognitive, and social dimensions.

In [137], the distances and sizes of pixels of the objects that systems for people with ASD use are established. The authors point out that 57 pixels is the minimum target size that touch systems must apply for users with ASD.

Studies such as those by Stavros Tsikinas and Stelios Xinogalos [138, 139] and Stéphanie Carlier et al. [140] propose and/or compile design guidelines available in the literature on serious games for people with ASD. In [138], a total of seven design guidelines for serious games for people with ASD are proposed based on existing design guidelines given in the literature: (1) feedback, (2) customization and personalization, (3) graphical interface, (4) game difficulty, (5) repetition, (6) motivators, and (7) participatory design. The authors in [139] compiled and created design guidelines for serious games that aim to

improve life skills in young adults with ASD and intellectual disability (ID). After a review of the literature, the authors define a "game design framework" that focuses on three axes: (1) pedagogy, (2) learning content and game mechanics, and (3) evaluation. In the research by Carlier et al. [140], serious games were created to reduce stress and anxiety in parents and children with ASD, and for their creation, eleven design guidelines found in the literature and six design guidelines based on the experiences of specialized therapists were considered.

10.1.2 UX-Related Research

Studies have proposed the creation of design guidelines for focused systems for people with ASD considering aspects such as usability, accessibility, and task-centered user interface design (TCUID) based on reviews in the literature and the characteristics of said users.

In [141], Chung and Ghinea discuss the use of technology to support the development of empathy in children with autism. Based on a review of the literature, a total of ten design guidelines are proposed and classified into four categories: graphical layout, navigation and structure, language, and interaction. The system was designed based on a human-centered design, and its acceptability and usability were evaluated through interviews, a survey of 12 sentences created based on the system usability scale (SUS) [18], defined design guidelines, and open-ended questions.

In a study by Khowaja and Salim [19], a total of 15 heuristics were defined based on Nielsen heuristics [7] and a compilation of 70 guidelines for the design and development of systems for children with ASD. These design guidelines were compiled after a review of the literature [142, 143, 144].

Hailpern et al. [145] described a real-time voice display system for people with ASD and speech delays (SPDs). The system was designed based on task-centered user interface design (TCUID), and after experiments and a review of the existing literature, a total of seven design guidelines were created. The proposed design guidelines are as follows: (1) minimize delay to interaction, (2) real-time is fun, (3) child customization, (4) dynamic computer correction, (5) robust microphone setup, (6) competence of the child, and (7) physical interaction.

Raymaker et al. [146] proposed a set of accessibility guidelines for websites used by people with ASD based on a website aimed at improving access to health care for autistic adults. The authors declare that they propose these accessibility guidelines based on the theory of accessibility and evaluate usability through evaluation surveys. A total of 20 accessibility guidelines are provided and are classified into three categories: physical accessibility, intellectual accessibility, and social accessibility.

In [147], a systematic review of the literature is employed to define a set of recommendations for the development of software solutions adapted for people with ASD. The set of recommendations, called AutismGuide, includes a total of 69 recommendations categorized into 11 categories: (1) general usability principles, (2) nonfunctional requirements, (3) functional requirements, (4) adaptability, (5) guidance, (6) workload, (7) compatibility, (8) explicit control, (9) significance of codes, (10) error management, and (11) consistency.

Tan-MacNeilla et al. [148] evaluated whether parents of children with neurodevelopmental disorders (NDD) perceived the Better Nights, Better Days (BNBD)

intervention as usable, acceptable, and feasible. To evaluate these aspects, the authors created questionnaires for before and after the intervention, which were completed by the users. The questionnaires were developed based on Morville's honeycomb model [10].

10.1.3 Nontechnological Intervention-Related Research

Studies have proposed different sets of design guidelines to be applied in places frequented by people with ASD. In Barakat et al. [149], a set of design guidelines is proposed to design a therapeutic garden for children with ASD with the objective of calming hyperreactive children and stimulating hyporeactive children with ASD. The design guidelines proposed by Barakat et al. [149] are classified under four categories: (1) visual principles as a therapeutic tool, (2) design elements as a therapeutic tool, (3) physical landscape features as a therapeutic tool, and (4) design guidelines, where the latter includes recommendations for security and safety and motor skills. McAllister and Maguire [150] proposed a total of 16 design guidelines for designing ASD-friendly classrooms. The 16 design guidelines specify the features of school environments that users interact with should include.

Although this research focuses on proposing UX factors to be used in technologies used by people with ASD, we believe that concepts such as promoting secure and safe environments and providing a transitional buffer before entering a classroom, among other characteristics, are necessary in any context that people with ASD interact with.

10.2 Two-Step Preliminary Proposal of UX Factors for ASD

Given the need to formalize the user experience evaluation process in systems focused on people with ASD, a methodical process was carried out to make a preliminary proposal of user experience factors for people with ASD that consider their characteristics, difficulties, and/or affinities, as found in the literature. The preliminary proposal of user experience factors was created following two steps, which are detailed below.

10.2.1 Step 1: Adapting Morville UX Factors Based on ASD Characteristics

As shown in Figure 6, a preliminary proposal of specific UX factors for people with ASD is defined based on (1) a search of the literature of the characteristics, difficulties, and/or affinities of people with ASD, and (2) the collection and selection of UX factors/attributes.

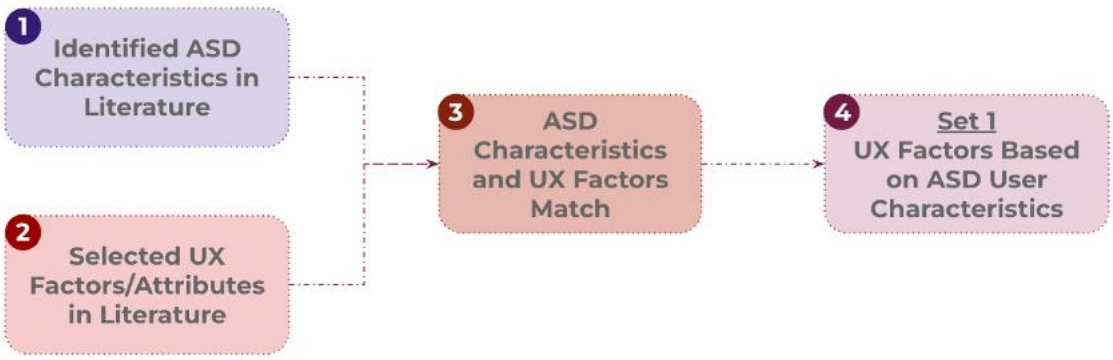

Figure 6. Process for Defining UX Factors Based on ASD User Characteristics

To perform this specification, we followed a four-step process to define specific UX factors for people with ASD: (1) the collection and grouping of characteristics, difficulties, and affinities in people with ASD; (2) the collection and selection of UX factors/attributes found in the literature; (3) matching identified characteristics and UX factors; and (4) the proposal of UX factors for people with ASD. Each step is detailed below.

10.2.1.1 Collection and Grouping of Characteristics/Difficulties/Affinities for People with ASD

In this step, we compiled and grouped the characteristics, difficulties, and affinities of people with ASD found in previous work [4, 8] and information provided by the book Diagnostic and Statistical Manual of Mental Disorders [1]. Following this process, we compiled a set of 18 characteristics, difficulties, and affinities, which are shown in Table 12.

Table 12. ASD Characteristics from the Literature

Characteristics/Difficulties/Affinities of People with ASD
People with autism spectrum disorder (ASD) tend to enjoy themselves and be engaged when interacting with computers, as these interactions occur in a safe and trustworthy environment [4].
People with ASD have a tendency to engage in visual and structured thinking [24].
Students on the autism spectrum enjoy playing games, as this provides a safe environment [2].
People with ASD experience difficulties with developing social skills [81], which leads to social isolation [82].
The delay of fine motor skills development causes difficulties with interaction [25].
People with ASD have difficulties when generalizing skills to real-world contexts [26].
People with ASD find real social interactions to be stressful and intimidating because they are unpredictable [43] as well as being initially frightening, challenging, and even undesirable.
People with ASD tend to be more susceptible to experiencing depression and frustration [27].
The patterns of restricted or repetitive behaviors that characterize people with ASD leads to problems with adapting to novel environments [1].
People with ASD show persistent deficits in social communication and social interaction across multiple contexts [1].
People with ASD exhibit deficits in social–emotional reciprocity [1].
People with ASD exhibit deficits in nonverbal communicative behaviors used for social interaction [1].

People with ASD exhibit deficits in developing, maintaining, and understanding relationships [1].
People with ASD exhibit restricted, repetitive patterns of behavior, interests, or activities [1].
People with ASD exhibit stereotyped or repetitive motor movements, use of objects, or speech [1].
People with ASD insist on consistency, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior [1].
People with ASD have highly restricted, fixated interests that are abnormal in intensity or focus [1].
People with ASD exhibit hyper- or hypo-reactivity to sensory input or an unusual interest in sensory aspects of the environment [1].

10.2.1.2 Collection and Selection of UX Factors

Authors have defined factors/attributes with the end goal of evaluating the usability and user experience of a specific product. Some examples of this include the following:

- Usability:
  - Aspects [28]: effectiveness, efficiency, and satisfaction.
  - Attributes [30]: learnability, efficiency, memorability, errors, and satisfaction.
- User experience:
  - Facets [31]: dependability, usability, playability, accessibility, plasticity, communicability, cross-cultural capacity, emotionality, desirableness, usefulness, and findability.
  - Factors [10]: useful, usable, desirable, findable, credible, accessible, and valuable.

The selection of such factors/attributes should be dependent on the nature and characteristics of the product and scope of the investigation. Considering the focus of this investigation, we selected the seven UX factors proposed by Morville [10], who states that the Useful, Usable, Desirable, Findable, Accessible, Credible, and Valuable factors contribute to a successful user experience. The definitions for each of these factors are presented in Table 13 below.

Table 13. Morville UX Factors

Factors Name	Definition
Useful	Content should be original and useful and fulfill a need.
Usable	Systems should be familiar, simple, easy to understand, and easy to use. The process of learning how to use a system should be as fast and simple as possible.

Desirable	Design elements such as images, identities, brands, and other features are used to evoke emotions and appreciation. The visual aesthetics of the product, service, and/or system should be attractive and easy to understand.
Findable	Information should be findable and easy to navigate. Users should be able to quickly find solutions to any problem encountered. The navigational structure should be set up in a way that makes sense.
Accessible	The product or service should be designed so that even users with disabilities can have the same user experience as others.
Credible	Products and services should be trustworthy and comply with their designed function.
Valuable	A product should deliver value to the business that created it and to the user who buys or uses it

10.2.1.3 Match between Identified Characteristics and UX Factors

After the compilation of the information described above, matching was employed. We matched the characteristics, difficulties, and affinities of people with ASD to the seven factors raised by Morville [10] to use these elements to specifically define what the user experience means for people with ASD.

To carry out the matching procedure, we performed the following steps: (i) for each of the seven UX factors, one or more characteristics, difficulties, and/or affinities of the users were associated, and (ii) a new specified UX factor was drafted to make it more specific to the selected characteristics. Table 14 presents an example of this mapping procedure, where we present characteristics that match the definition for Morville's "findable" factor, and then we define an adapted UX factor for people with ASD. Appendix C presents the matching results for all seven of Morville's UX factors.

Table 14. Sample of UX Factors Specified for ASD

Morville UX Factor	**Characteristics/Difficulties/Affinities of People with ASD**	**UX Factor for People with ASD**
Findable	• Stereotyped or repetitive motor movements, use of objects, or speech [1]. • Insistence on sameness, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior [1]. • People with ASD have a tendency to engage in visual and structured thinking [24]. • Patterns of restricted or repetitive behaviors that characterize people with	• Information and navigational setup should be structured and consistent to adapt to the inflexible and structured thinking of users with ASD. • The users should be able to quickly find information and solutions to any problem to facilitate adaptation to novel environments and avoid frustration.

	ASD leading to problems with adapting to novel environments [1].	

10.2.1.4 Preliminary Proposal of UX Factors for People with ASD Based on Characteristics

After collecting, analyzing, and refining the information described in the above sections, eight specific UX factors for systems used by people with ASD are proposed. Table 15 presents a preliminary definition for each of the factors.

Table 15. Set 1: Preliminary Definitions of UX Factors Based on ASD User Characteristics

UX Factor	Definition
Safe	The system should provide a safe environment to help users fulfill their needs. Design elements should evoke emotions and appreciation, ensuring a safe and trustworthy environment through technology.
Predictable	The system and its content should be predictable and not stressful or intimidating to create a trustworthy context for users.
Generalizable	The system, including its aesthetics, audio, and inputs, should be familiar enough and similar enough to real life to facilitate interpretation and the generalization of skills.
Structured	Content, visuals, and navigational layouts should be structured, consistent, and controlled to appeal to the structured and visual thinking of the users.
Valuable	The system should have perceived value for its users.
Easy	The system should be designed to be easy to use, enjoyable, and engaging for users with and without ASD.
Sociable	The system should consider deficits in social interaction when including any social elements in its design (providing tools to facilitate social interactions when needed).
Frustration Free	The system should prevent frustration in users through its design and error management so users can quickly adapt to novel environments and find information and solutions to any problem.

10.2.2 Step 2: Guidelines from the Literature

In a second step, as shown in Figure 7, after a review of the literature, we identified and compiled design guidelines and/or recommendations defined by authors based on the characteristics of people with ASD in technological and nontechnological contexts.

Figure 7. Process for Defining UX Factors Based on ASD Guidelines and Recommendations

We followed a three-step process to define UX factors for people with ASD based on ASD guidelines and recommendations: (1) the compilation of articles that propose and/or use design guides and/or recommendations, (2) grouping and categorizing design guidelines and/or recommendations based on their similarities, and (3) the proposal of a second set of UX factors for people with ASD.

10.2.2.1 Identifying Guidelines in the Literature

After a recent literature review, a total of 16 articles were found to focus on proposing and/or using guidelines to design systems or places frequented by people with ASD. From these articles, 290 design guidelines or recommendations were identified and are presented in Table J under the names or identifiers given by the authors. For studies [143, 144], only the number of guidelines is shown since the authors do not provide short identifiers for them.

The studies present varying amounts of design guidelines and/or recommendations, which are generally focused on different aspects to consider when designing systems or interventions for people with ASD. These differences between quantities and categories may be attributable to this being a little explored field, and there is no consensus or established definition of aspects to consider when working with people with ASD, which supports the need to specify and agree on these aspects.

10.2.2.2 Grouping and Categorization

Following the results given in Table J, the 290 design guidelines or recommendations found were grouped and categorized according to similarities in their definitions. In Table K, the design guidelines or recommendations are categorized into 10 categories, which are divided into 32 subcategories of aspects to be consider when designing systems for people with ASD. For each of the subcategories, we cite a representative phrase for the group as an example selected from a study that considers this guideline or recommendation. An example of the grouping and categorization of guidelines and recommendations is given in Table 16. The full process employed is documented in Table K.

Table 16. ASD Guideline and Recommendation Categorization

Category	Subcategory	Definition	Sources
Structure, Repeatability, and Predictability	Structured	"Children with autism thrive in a structured environment. Establish a routine and keep it as consistent as possible." [144]	[8, 141, 143, 144, 146]
	Repetition	"Children with autism generally enjoy repetition and may engage in repetitive activity to the detriment of other activities." [143]	[136, 140, 142, 143, 144, 147, 149]

	Consistency	"The system should use clear and consistent language so that users do not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions in the design for consistency." [19]	[19, 136, 140, 141, 144, 146, 147]
	Predictability	"When working with people with autism spectrum disorder, it must be ensured that we provide a structured and predictable learning environment, since people with ASD have restricted and repetitive patterns of behavior, interests or verbal and non-verbal activities." [8]	[8, 136, 140, 141, 143, 144, 147]
	Control	"Software solutions designed for users with ASD must ensure that they always have control (e.g., pause, restart) over the computer processing." [147]	[143, 144, 147]

As shown in Table K, multiple studies establish design guidelines and/or recommendations for aspects to consider when designing systems for people with ASD. Aspects such as personalization, customization, and graphics are most frequently considered in design guidelines and/or recommendations proposed in studies given the diverse characteristics and affinities that users may have. In contrast, aspects such as a simple and concise memory load, control, and recovery are the least explored by research.

10.2.2.3 Preliminary Proposal of UX Factors for People with ASD Based on Design Guidelines

Considering the grouping of similar concepts described in Table K, a second set of refined preliminary UX factors for people with ASD based on design guidelines and/or recommendations is established. This refined proposal considers a total of eight UX factors, establishing an identifying name and specific definition, as shown in Table 17.

As the objective of our research is to establish UX factors that allow us to evaluate software systems designed for people with ASD, we eliminate the category "External Agents" presented in Table K because it focuses on aspects external to software.

Table 17. Set 2: Preliminary Proposal of UX Factors Based on ASD Guidelines and Recommendations

UX Factor	Definition
Engagement	Systems designed for people with ASD must engage users through feedback, rewards, and motivational elements.
Tasks and Interaction	Systems for people with ASD should include tasks and interactions that consider the characteristics, affinities, and needs of the users. Tasks must evolve; be designed in a simple and concise way; have a single, clear, and explicit objective; and keep the memory load low.
Generalizable	Systems for people with ASD should be familiar to users. Known and/or previously learned elements must be included to facilitate their interpretation and thus their generalization to daily life.
Customization and Personalization	Systems for people with ASD must be customizable and easily personalized. The system must adapt to the characteristics of the users while also allowing users and tutors to flexibly personalize the characteristics of the system.
Senses	Systems for people with ASD must consider the senses of the users. The eventual rejection of visual, auditory, and physical stimulation should be considered.
Structure, Repeatability, and Predictability	Systems for people with ASD should be structured and predictable and allow for the repetition of actions.
Attention and Timing	Systems for people with ASD must retain users' attention, manage timing appropriately, and avoid the involvement of distracting elements during interaction.
Error Management	There must be error management in systems for people with ASD. Systems must facilitate the prevention and recognition of and recover from eventual errors that may occur during interactions with users by communicating clearly and accurately through a simple language that is familiar to users.

10.3 A Set of UX Factors for People with ASD

Given the definitions established in set 1 (Table 15) and set 2 (Table 17), the preliminary UX factors were merged to formulate a proposal of UX factors for people with ASD, as shown in Figure 8. In this proposal, a total of nine UX factors are defined: Engaging, Predictable, Structured, Interactive, Generalizable, Customizable, Sense-aware, Attention retaining, and Frustration Free. Definitions for each of the proposed UX factors are presented in Table 18.

In this set of UX factors, concepts such as "Engaging" or "Interactive" are included, which can be applied in contexts where learning is the focus of research. We believe that each of the proposed factors contributes to evaluating systems designed for people with ASD in general contexts and is not limited to learning settings. The nine UX factors established for people with ASD can be used to identify the most important or interesting areas that can be developed or addressed when designing systems for people with ASD. Defining these

factors helps elucidate what UX implies and means and what is essential for ASD users. Additionally, we believe that these nine UX factors can contribute to adapting or creating new UX evaluation instruments and/or methods, which could contribute to the improvement of UX for systems designed for people with ASD.

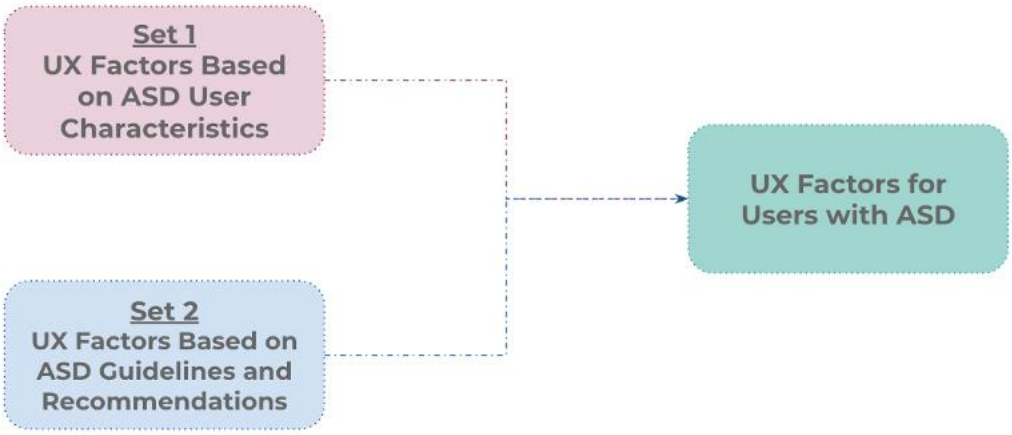

Figure 8. Process of Defining Final UX Factors for Users with ASD

Table 18. UX Factors for Users with ASD

UX Factor	Definition
Engaging	Systems for people with ASD must engage users. To encourage engagement from users, the system must provide: (1) feedback in a constant, concrete, and accurate way regarding the user's actions, (2) rewards in response to good performance, and (3) motivating elements such as the use of game elements and visual or auditory elements that are attractive.
Predictable	Systems for people with ASD must provide a predictable environment. Allowing the repetition of actions and providing a high level of control over the system in a friendly and safe environment will help generate a predictable and reliable context to interact with.
Structured	Systems for people with ASD must be structured. Providing clearly structured, simple, and consistent graphic, navigation, and interactive elements during system use will generate a safe and reliable environment for users.
Interactive	Systems for people with ASD must generate interactions based on the characteristics, affinities, and needs of users and based on their difficulties with social interactions. Tasks must evolve and increase in difficulty based on learning and adaptation pace. The proposed tasks must be designed in a simple and concise way and have a single objective that is clear and explicit. Memory load should be minimized during all interactions with the system. Instructions with adequate and concise language should be presented given an affinity for visual learning among people with ASD.

Generalizable	Systems for people with ASD should be familiar to users. They must have visual elements, audio, and known and/or previously learned inputs to facilitate interpretation and thus generalization to daily life.
Customizable	Systems for people with ASD must be customizable. The system must adapt to the characteristics, affinities, and needs of users. Users and tutors should be allowed to flexibly personalize aspects of the system, including colors, textures, font sizes, and volume levels, among other aspects, so that the system is easy to use, pleasant, and attractive for users.
Sense-aware	Systems for people with ASD should consider the users' senses. The system must provide a simple, readable, clear, and understandable layout with physically spaced elements in its interfaces. Pleasant graphics should be provided for users, prioritizing a minimalistic aesthetic and avoiding the use of distracting or anxiety-provoking colors. Use a familiar and simple language for users, and prioritize the use of icons/symbols. Sensory overload should be avoided, so do not saturate sites with information, images, audio, or text. When using sounds to interact with users, ensure they are clear, simple, functional, and nondisruptive. Potentially reduced motor skills should be considered through the use of touch screens, non-touch interfaces, and hybrid options.
Attention Retaining	Systems for people with ASD must retain the attention of users by managing timing appropriately. The timing of transitions should be minimized, and users should be given enough time to interact with the system. The system should have elements that help with attention retention, such as dynamic stimuli, while not including elements that could be distracting or cause sensory overload.
Frustration Free	Systems for people with ASD should prevent the frustration of users during interactions. Error management should be considered to prevent potential errors, easily recognize errors, and facilitate recovery from any unwanted state. It is important to communicate any errors clearly and accurately using simple language that is familiar to users.

10.4 Summary and Discussion

Several studies have evaluated the UX and/or usability of systems for people with ASD. However, as evidenced in previous studies [4] and given the present investigation, empirical evidence and sufficient details are not presented to help us evaluate UX in systems for people with ASD. Additionally, it should be noted that no research has discussed UX factors of systems for people with ASD. Given the characteristics, affinities, and needs of people with ASD, we believe that it is pertinent to explore and specify UX factors that help evaluate systems designed for these users.

Given that there is no consensus on how to design specific UX factors regardless of the contexts in question, we used two means of search and information capture to establish guidance on UX factors for people with ASD.

The first approach focused on compiling the characteristics, affinities, and needs of people with ASD found in the literature as well as existing UX models. Since the UX models

found do not consider the characteristics of people with ASD, we considered Morville's honeycomb [10] model, and we tailored it to the characteristics, affinities, and needs of people with ASD. In this way, a first set of UX factors for use in systems designed for people with ASD was established.

The second approach involved compiling design guidelines and/or recommendations from the literature focused on technological systems for people with ASD. The design guidelines and/or recommendations found were grouped and classified to establish a new set of UX factors specific to systems designed for people with ASD.

We believe that these two approaches helped us analyze different perspectives on how the creation of specific UX factors should be carried out. An established UX factor creation methodology would have helped further support our research. We believe that the methods adopted helped us establish a good proposal on specific UX factors for systems designed for people with ASD.

In combining our preliminary UX factor proposals, we define a final set of UX factors for people with ASD that includes nine UX factors: Engaging, Predictable, Structured, Interactive, Generalizable, Customizable, Sense-aware, Attention Retaining, and Frustration Free.

These nine UX factors lead to a new UX model for people with ASD. The UX factors can be used to design appropriate systems for users with ASD. We believe that this set of UX factors will provide a theoretical basis for the possible adaptation or creation of evaluation instruments, methods, and methodologies and for the development of recommendations and design guidelines. These factors will help complete and enable future research that seeks to evaluate systems for people with ASD.

We believe that each of the established UX factors complements the others and that systems designed for people with ASD that comply with these factors will provide added value and will increase the satisfaction of users who interact with this system.

11 UX METHODS SELECTION

Given the lack of specific methods to evaluate UX in people with ASD [4], we investigated general UX methods that can be used in systems, products or services to be used by people with ASD. We selected six methods based on the information found in previous work [4] and methods presented on the website www.allaboutux.org [128].

The selection criteria have been based on our previous work where we studied the affinities and characteristics of people with ASD [4, 8]. In [4] a systematic literature review was carried out on the use of technology to teach people with ASD, and how these studies consider and evaluate usability, accessibility and UX. In [8] a total of eleven studies were analyzed, which were selected from the category of "social skills" of the previous systematic review of the literature [4], in order to understand how they characterize the difficulties of people with ASD, how these characteristics are used to design their proposals, the results obtained, and possible recommendations, in order to define design guidelines and best practices for future technology interventions that meet specific needs in people with ASD.

One of the most recurrent criteria we used to exclude methods was reviewing if they use individual and group questionnaires, are focused on emotions, and if they use images with facial expressions. The six selected methods are presented below:

1. **Controlled Observation** [151]: This method is focused on evaluating the effect of particular design decisions over the user satisfaction when using of a product or system, isolating these decisions to obtain noise-free data. This is achieved by individually controlling each of the design decisions through hard and balance controls over the order and execution of specific tasks by the participants within a controlled environment (often carried out in specific laboratories). Some of the controls used are task-ordering, which eliminates noise caused by prior knowledge when performing similar activities, and applying extremely controlled conditions by eliminating any environmental distraction that could affect the user's response to the product, including noise from conversations or other elements in the participant's field of vision. This method allows obtaining "pure" information and detecting less visible or specific effects on design decisions.
2. **Property Checklists** [151]**:** This method consists of a checklist related to a series of design properties that would affect the utility of the product, in order to verify that design objectives are met. This list refers to high-level properties, such as consistency, compatibility and good feedback, and low-level properties, such as the color, position and size of characters on the screen. The purpose of these checklists is that an expert usability evaluator can verify that the design of the product is adjusted to what is described in the list.
3. **Field Observations** [151]**:** This method is based on observing the users/participants in the environment in which they would naturally interact with the system or product. The purpose of this evaluation is to understand how participants experience the interaction of the system in natural conditions without limiting restrictions that could arise from a pre-established investigation. The role of the researcher during the observation process should be as minimal as possible, since the participants can modify their behavior consciously or unconsciously during the observation.

4. **Group-based expert walkthrough** [152]: This method considers usability inspections based on task scenarios, in order to identify usability problems, design improvements and successful/good design solutions of a product or system. In order to carry out this evaluation, it is suggested to be carried out between 5-6 expert evaluators in the domain, which may not have knowledge in usability inspections, guided by a leader who must be a usability expert. The Walkthrough consists of task scenarios, structured enough for any non-usability evaluator to be able to participate, where the leader guides evaluators step-by-step through the product or system and evaluators take notes individually, and then in a second walkthrough, each of the evaluators' opinions is compiled through a group discussion for each of the tasks performed.
5. **Perspective-Based Inspection** [153]: This method applies a usability inspection of several sessions, which focus on detecting a subset of usability problems by inspectors/evaluators who perform a set of tasks, guided by a set of particular guide questions, considering different perspectives. These perspectives should be mutually exclusive, since it is stated that the set of perspectives would help to detect more problems than the use of traditional inspection techniques. The authors detail that the model helps to identify two categories of usability problems, such as "gulf of execution", which refers to the differences that arise between the intentions that users have and the actions that the product allows or system, and “gulf of evaluation”, which refers to the discrepancy between the system's representation and the expectations of the user of this system.
6. **Heuristic Evaluation** [7]**:** This evaluation consists of examining and judging the compliance of selected usability principles (“heuristics”) of an interface/system, by the inspection of a group of evaluators (ideally between 3 to 5). This evaluation presents four sequential stages, (1) the first individual stage: each of the evaluators evaluates the system and generates a list with the potential usability problems that were detected. (2) first group stage: together, the evaluators make a unique list of potential problems detected based on the findings in the previous stage, associating each of these with a heuristic from the selected set of heuristics. (3) second individual stage: each evaluator rates each of the potential problems based on its frequency, occurrence of said problem during the use of the system/interface, and its severity, the negative impact that said problem generates on the use of the system. Then, these values (frequency and severity) are added, resulting in the criticality of said problem. And the (4) second group stage: together, the evaluators gather the information in the previous stage and calculate the averages of the frequency, severity and criticality for each problem.

The methods described above have been chosen after a first search for usability methods present in the literature, so these could be eliminated, or other methods could be added to this selected set. It is worth mentioning that possible modifications or adaptations to these methods are proposed for their proper use given the characteristics of people with ASD.

12 METHODOLOGY TO EVALUATE THE USER EXPERIENCE FOR PEOPLE WITH AUTISM SPECTRUM DISORDER

It is important that the process to evaluate the user experience (UX), as well as the evaluation methods and instruments, are selected and adapted considering the specific characteristics of users with ASD, to ensure a positive and rewarding experience when interacting with systems, products or services.

Multiple studies have looked on how to evaluate UX in systems, products, or services used by people with ASD, however most of these studies do not present sufficient details of the evaluations performed and show a lack of empirical evidence [4]. Investigations have proposed different ways to evaluate UX and usability in their proposals, through different evaluation methods, which are defined as "a procedure composed of a series of well-defined activities for the collection of data related to the interaction of the end user (…)" [33], such as the system usability scale (SUS) [18] and heuristic evaluation [7], and instruments, which are a set of elements used by an evaluation method that can vary depending on the application's context. Many of the evaluation methods and instruments used in the evaluations are not adapted to the characteristics and needs of people with ASD.

Considering this, the objective of this paper is to present a three-stage methodology to evaluate the user experience for people with ASD, as there is a need for a formal methodology to evaluate user experience that is built upon the needs and characteristics of users with ASD and provides proper guidelines and evaluation methods for them.

This methodology was developed by researching the characteristics of the users through a systematic literature review [4], proposing a set of adapted UX factors [11], selecting evaluation methods suitable for the needs of users with ASD, and defining a logical step-by-step process to select evaluation methods to execute, plan the experiments, select evaluators and participants, carry out the selected methods, and perform qualitative and quantitative analysis, which results in a detailed report on the UX of the system, product or service evaluated.

A preliminary version of the methodology was published in 2021 [9], which was reviewed and validated through the opinion of three experts in UX and later via an expert judgement validation by 22 experts with knowledge on UX, ASD and/or both, which resulted in the proposal presented in this paper.

This document is organized as follows: Section 12.1 describes relevant related work; Section 12.2 presents the UX evaluation methodology for people with ASD; and section 0 presents our conclusions and future work.

12.1 Related Work

To complement our findings in a previous systematic literature review [4], we have reviewed the literature that has emerged since the year 2019 in order to update the conclusions previously obtained regarding these related studies.

In recent times, the amount of research focused on developing systems and/or products for people with ASD has increased, which is possibly due to the growing interest in the affinity that people with ASD have with technology.

For systems and/or products developed for people with ASD to be friendly and usable, research has evaluated the satisfaction and/or perception of experts in the domain (psychologists, differential teachers, speech therapists), tutors and/or people with ASD, through different evaluation methods.

Studies have evaluated their proposals through the application of simplified and/or complete versions of the system usability scale (SUS) [18]. Some studies have modified the SUS scale (using simplified language, incorporating emoticons, or reducing the scale) when used with users with ASD [154, 155]. Other studies have evaluated their proposals with experts in ASD and/or tutors of users with ASD, using the SUS scale in its complete [156, 157, 158] or reduced [159] version.

Other researchers have evaluated their proposals through sets of heuristics. Ramos-Aguiar and Álvarez-Rodríguez [160] state that they have evaluated their proposed application using Nielsen's heuristics [161]. Camargo et al. [162] mention having evaluated their mobile application with a heuristic evaluation using the Semiotic Interface sign Design and Evaluation (SIDE) framework [163].

Studies mention having evaluated their proposals using questionnaires. Susanti et al. [164] have evaluated the usability of their application through "direct observation" of users interacting with the application and the execution of the questionnaire proposed by Sehrish Khan [165] which aims to assess usability based on five categories: (1) ease of use, (2) learnability, (3) feedback and good error messages, (4) adequate help and documentation, and (5) appealing interface. Ghabban et al. [166] propose to evaluate their proposal through the creation of a new questionnaire model called M-UTUAT, which is based on seven attributes of the People at the Center of Mobile Application Development (PACMAD) model [167] and three factors of the Unified Theory of Acceptance and Use of Technology (UTAUT) model [168].

Multiple investigations have evaluated their proposals based on a set of evaluation methods. Ahmed et al. [169] mention having evaluated the usability of their proposal with the participation of people with ASD, through the application of three evaluation methods: (1) system usability scale (SUS) [18], (2) VR sensitivity scale and (3) a heuristic evaluation with the Nielsen set of heuristics [7]. Adiani et al. [170] state that they have evaluated their proposal with professionals, parents/caregivers and children with ASD through three evaluation methods: (1) system usability scale (SUS) [18], (2) Acceptability, Likely Effectiveness, Feasibility, and Appropriateness Questionnaire (ALFA-Q) [171] and (3) semi-structured Customer Discovery style interviews. Kim et al. [172] present a process based on four phases, where phase three aims to evaluate the usability of the proposed mobile application through a set of methods. In it, 18 people (9 people without ASD and 9 people with ASD) have been asked to participate in the execution of four evaluation methods sequentially. The evaluation methods used were: (1) Demographic Survey, (2) Think-Aloud Protocol [173], (3) Cognitive Walkthrough [174] and (4) system usability scale [18].

Studies in recent years show interest in evaluating the usability and UX in systems and/or products used by people with ASD. Evaluation methods, such as the system usability scale (SUS) [18] and the use of Nielsen's set of heuristics [161], are widely applied to find usability problems and provide an overview of the user's satisfaction of the system, product

or service; however, we consider that the level of detail obtained is not sufficient to cover the particular needs that a user with ASD has when interacting with the evaluated system.

Methods, such as the Think-Aloud Protocol [173] and Cognitive Walkthrough [174], are useful to obtain information on the perception of the system directly from the final user of the system; however, by depending on the insights of people who may have communication deficits [1] and are susceptible to frustration [27], this method can deliver unreliable results for users with ASD, so it is necessary to have special considerations regarding its implementation, as well as the environment and the way in which we communicate with the user during the test.

In general, we believe that (1) the investigations must have a greater specification detail on the evaluations carried out, (2) the methods and instruments used must consider the characteristics and needs of people with ASD (example: there must be a set of heuristics focused on people with ASD), and also (3) we believe it is important to have the participation of UX/Usability experts, ASD experts, tutors and people with ASD.

12.2 A Methodology to Evaluate UX for People with ASD

Considering that literature do not present enough detail in the evaluations nor empirical evidence in their research, we believe that it is necessary to formalize the UX evaluation process in systems, products and services used by people with ASD. For this, we have created a three-stage methodology (see Figure 9). This methodology focuses on evaluating the UX of systems, products or services used by adults with ASD level 1, as defined in the DSM5 [1]. The methodology aims to maximize the amount of valuable information obtained about the UX of the system, product, or service, so that it can be used to improve the UX and therefore their use is satisfactory for people with ASD.

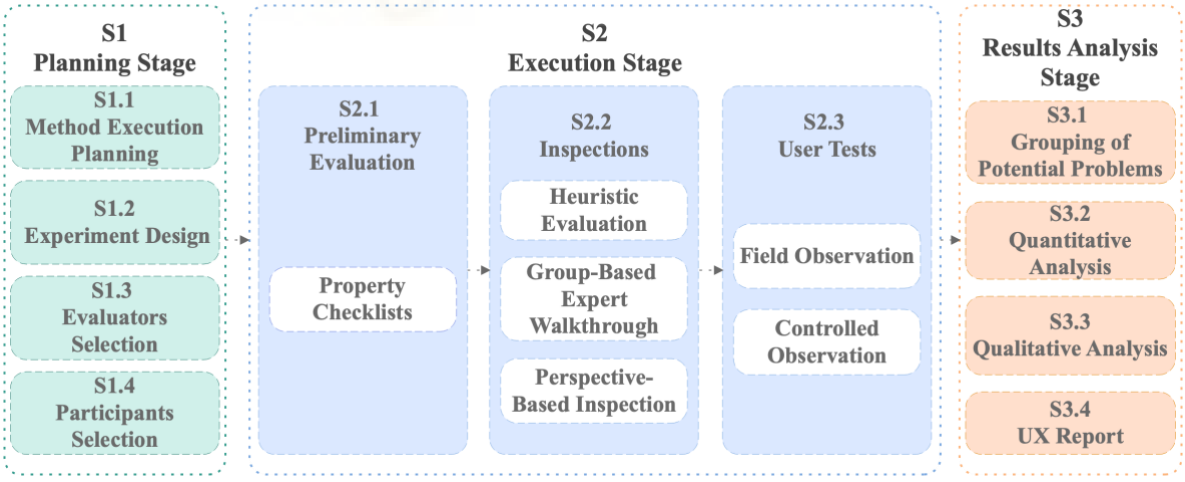

Figure 9. Stages of the UX evaluation methodology for people with ASD

The methodology proposes three sequential stages, starting with the Planning Stage (S1), followed by the Execution Stage (S2) and ending with the Results Analysis Stage (S3). All stages and substages can be seen in Figure 9.

To facilitate the reading of the methodology the stages and substages are identified with unique IDs (such as S1, S2, S1.1), and their outputs with numerical icons (①, ②, ③), which are consistent with the diagram and tables presented in this document. Figure 10 presents a general description of the methodology and its stages, as well as the inputs and outputs of each of these.

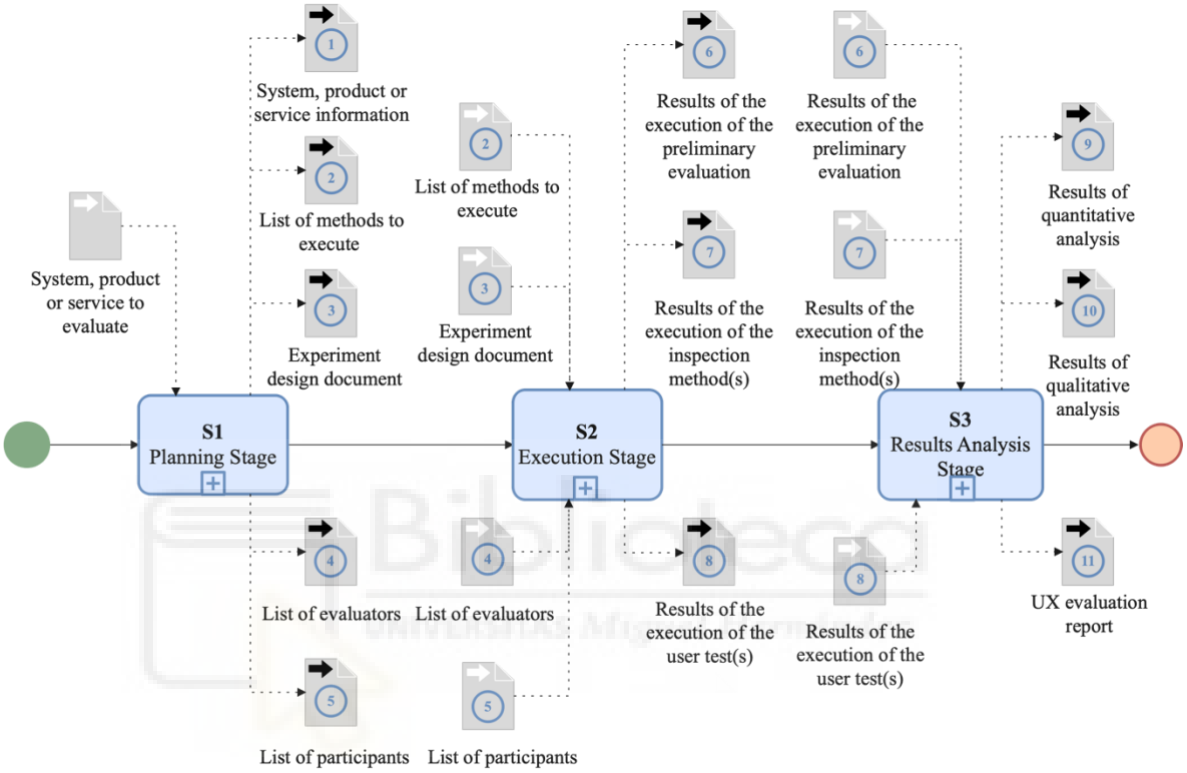

Figure 10. General description of the methodology

When applying the methodology, consider:

- Carry out all the stages and substages proposed in the methodology. Consider that the execution stage has a set of substages, which in turn are made up of one or more evaluation methods.
- The methodology is flexible about which evaluation methods can be carried out in the execution stage. The choice of evaluation methods will depend on the criteria of the researchers, based on the objective of the evaluation, autonomy, and dependence of the participants, resources, and time available.
- Depending on the stage and substage, one or more documents will be required to start it. Similarly, executing each stage and substage will result in one or more documents.

Next, each of the stages and substages of the proposed methodology are presented in detail.

12.2.1 S1 Planning Stage

The purpose of the planning stage is to plan the UX evaluations to be carried out, as well as to search for UX/Usability experts, domain experts (professionals who work with people with ASD), participants and tutors. For more detail, see substages S1.1, S1.2, S1.3 and S1.4.

It is important to consider that before beginning this first stage, the system, product, or service to be evaluated, its characteristics and limitations, must be identified, as well as its target user.

As complementary material, Table L is presented in appendix D, which describes what is needed, what to do and what is obtained as an output when implementing this stage. Additionally, a BPMN diagram of the steps to follow in this stage is presented in Figure A, available in appendix E.

12.2.1.1 S1.1 Method Execution Planning

The purpose of the method execution planning substage is the selection and planning of the evaluation methods to be executed.

To determine and select the UX evaluation methods to apply to the system, product, or service to be evaluated, you must consider: (1) the objective and scope of the UX evaluation must be defined. The methods and activities must focus on the defined objective and scope; and (2) the resources and times available to carry out the UX evaluations must be established.

Depending on the objective of the evaluation, scope, resources, and available time, it is necessary to choose which methods to select. Based on the time and resources available, we propose the execution of the following sequences of evaluation methods:

- If you have enough time and resources, carry out each of the methods presented in the methodology (as shown in Figure 9).
- If you do not have enough time and resources are limited, execute only the following evaluation methods: property checklist, heuristic evaluation and field observation, since these are considered the baseline of the methodology.
- In any other case, select evaluation methods based on the complexity of each method. We suggest that:
    - Always execute the property checklists method.
    - Carry out at least one method of the inspections substage (S2.2) and the user tests substage (S2.3).
    - Depending on the time and resources available, one or more inspection methods can be carried out, selected according to the objective of the evaluation and the needs of the study. The order of the inspection methods of substage S2.2, from less to more complex, in terms of effort and resource requirements, is: heuristic evaluation, group-based expert walkthrough and perspective-based inspection.
    - Depending on the remaining time and resources, it is recommended to perform the "field observation" method if less time and resources are available, otherwise use the "controlled observation" method.
- If necessary, you can select and modify the selection of methods to use as you progress through the run stage.

Also consider selecting and/or adapting instruments of the evaluation methods to be carried out which are suitable for the needs of users with ASD. The instruments used in each of the selected methods must be particularized for people with ASD and the type of system,

product, or service to be evaluated (e.g., select a set of heuristics for transactional systems for people with ASD).

As complementary material, Table M is presented in appendix D, which describes what is needed, what to do and what is obtained as an output when implementing this substage. Additionally, a BPMN diagram of the steps to follow in this substage is presented in Figure B and Figure C, available in appendix E.

12.2.1.2 S1.2 Experiment Design

Once the evaluation objective, scope and methods that will be executed in the UX evaluation process are defined, a set of important aspects for the experiments to be carried out must be created and defined. These aspects are:

- Define the evaluation objective(s) for each method to be carried out.
- Define the expected results that will be obtained for each activity to be carried out in the UX evaluation methods.
- Define scenarios and tasks. Consider that:
    - In case of executing at least two evaluation methods that require scenarios and/or tasks, create universal scenarios and/or tasks, which can be used by multiple evaluation methods to reuse and optimize resources.
    - The design of tasks and scenarios must consider the characteristics and needs of people with ASD. The instruments to use in each evaluation method in this methodology should be adapted according to the recommendations described in this document, in order to maximize the value for people with ASD.
    - The scenarios and/or tasks created should focus on specific characteristics of the system, product, or service. Similarly, scenarios and/or tasks should be concise and clear.
    - In case of executing the "controlled observation" method, include an estimated time for completion, and the expected results of each task. These can be compared with the time that the participant took to perform the task, and the results obtained from it.
    - It is important to keep in mind that participants may require more time to understand the tasks to be performed, as well as more time to be prepared for the activity and to finish it. It can be frustrating for some users with ASD not to have enough time to complete the activities due to their strict routines [1].
- Define protocols (set of documents required for the execution of the evaluation methods). Consider:
    - *Confidentiality agreement:* In the case of the implementation of methods that require an audiovisual record of the actions of the participants, confidentiality agreements must be established. The purpose of the confidentiality agreement document is to inform the participant that their actions will be recorded, their identities will not be revealed, and that the purpose of the experiment is to evaluate the system, product, or service and not their abilities, skills, or knowledge.

- *Preliminary questionnaire (demographic):* Experts and participants should be provided with a preliminary (demographic) questionnaire prior to performing the evaluation methods. The preliminary (demographic) questionnaire aims to identify the profiles and previous experiences that evaluators or participants may have with similar systems, products, or services.
- *Perception questionnaire:* At the end of the execution of an evaluation method, the evaluators or participants must be provided with a system, product, or service perception questionnaire. The purpose of the questionnaire is to find out the different perceptions that the evaluators or participants have about the system, product or service evaluated and the tasks performed.
- *Observer logs:* We recommend that UX leaders and/or researchers (in the role of observers) record what was observed during the method execution process in logs. Record potential problems, comments out loud from participants or evaluators, or information that UX leaders or researchers deem necessary in the logs.
- *List of tasks:* In the case of carrying out evaluation methods where a set of tasks is needed, create two documents with the list of tasks: (1) list of tasks for the evaluators or participants during the experiment, with the goal of providing a sequence of tasks to perform during interaction with the system, product or service; and (2) list of tasks for researchers and/or observers, which details the expected results and expected time for each proposed task.
- *List of potential problems:* Evaluators or observers should be asked, depending on the method to be carried out, to record the potential problems found through the evaluation (see the execution stage). It is expected that at least one definition, explanation or comment on the potential problem encountered will be provided. Once the potential problems have been identified, each evaluator and/or observer must assign a value of severity, frequency, and criticality to said problems, under the same evaluation scale (see Table N).

- All documents delivered to participants must have clear and concise instructions, and if necessary, have visual support.
- All protocols presented must be established and documented in the Experiment Design document, which will be a necessary input to carry out each of the methods in the execution stage. The details and information provided to the evaluators or participants will depend on the evaluation method to be carried out, as established in the S2 execution stage.

As complementary material, Table O is presented in appendix D, which describes what is needed, what to do and what is obtained as an output when implementing this substage. Additionally, a BPMN diagram of the steps to follow in this substage is presented in Figure D, available in appendix E.

12.2.1.3 S1.3 Evaluators Selection

Search and select evaluators to participate in the execution of the UX evaluation methods proposed in the execution stage. We recommend that:

- The profiles of these evaluators must be: (1) experts in UX/Usability, (2) experts in the specific domain (professionals who work with people with ASD, for example psychologists, speech therapists and differential teachers), and/or (3) preferably experts with knowledge in both areas (UX/Usability and in the ASD domain).
- Have three to five evaluators [175] for each of the inspection methods to be carried out. Having the support of different professionals will help to include different points of view in the analysis and, eventually, find a greater diversity of potential UX problems.
- Have an expert who assumes the role of leader. This can be an expert with knowledge in both areas (UX/Usability and in the ASD domain) or a UX/Usability expert. The expert must accept this role and lead each of the evaluation methods to be carried out on the system, product, or service.
- In case of executing more than one inspection method, it is recommended to have different evaluators for each method to have different points of view and avoid possible biases.
- Evaluators who are experts in ASD or related areas will be responsible for guiding and educating the other evaluators on how to deal with users and their specific needs during user testing. Each user is different, and their needs may not be visible to an evaluator without ASD domain experience.

As complementary material, Table P is presented in appendix D, which describes what is needed, what to do and what is obtained as an output when implementing this substage. Additionally, a BPMN diagram of the steps to follow in this substage is presented in Figure E, available in appendix E.

12.2.1.4 S1.4 Participant Selection

Define and select the users who will be participants in the experiments to be carried out in substage S2.3 (User Tests), considering the target users of the system, product, or service to be evaluated. We recommend:

- Have three to five participants with ASD [175] for each of the evaluation methods of tests with users (controlled observation and field observation).
- If necessary, we recommend including tutors close to people with ASD, to create a safe environment for the participants. The tutors will take a guiding role for the participants with ASD, in case they are overwhelmed by the task or instructions given. Tutors must not intervene in the participant's interaction with the system, product, or service.
- In the case of executing the two test methods with users (controlled observation and field observation), it is recommended to use different participants for each method, to have different points of view and avoid possible biases.

As complementary material, Table Q is presented in appendix D, which describes what is needed, what to do and what is obtained as an output when implementing this

substage. Additionally, a BPMN diagram of the steps to follow in this substage is presented in Figure F, available in appendix E.

12.2.2 S2 Execution Stage

The execution stage has the purpose of executing previously selected methods to evaluate the user experience of systems, products, or services for people with ASD.

Before executing an evaluation method and considering the knowledge of the evaluator, it is recommended:

- For expert evaluators in UX and/or Usability: give them a brief induction on the ASD condition and its main characteristics.
- For expert evaluators in the ASD domain: give them a brief introduction to UX and the evaluation methods to be executed.
- Both groups of evaluators should be given a brief introduction about the system, product, or service to be evaluated, indicating its purpose, objective, and scope of the evaluation.
- The methods proposed in this methodology have been selected considering the characteristics of people with ASD, and they can be used to assess a variety of systems, products, or services for any type of user. Therefore, any necessary adjustments should be considered for their instruments or environment of execution.
- The proposed evaluation methods can be executed sequentially or in parallel. The order of execution will depend on the decisions made by the investigators.

As complementary material, Table R is presented in appendix D, which describes what is needed, what to do and what is obtained as an output when implementing this stage. Additionally, a BPMN diagram of the steps to follow in this stage is presented in Figure G, available in appendix E.

Next, the aspects to be considered when executing the proposed methods and instruments are detailed.

12.2.2.1 S2.1 Preliminary Evaluation

First substage of the execution stage. It consists of the implementation of the property checklist inspection method, to evaluate the usability of the system, product, or service in a preliminary way.

Property Checklists

The use of the property checklist evaluation method [151] as the first inspection method to be executed in the proposed methodology, aims to quickly detect the deficiencies or pain points that can be found in the evaluated system, product, or service. Conducting this initial assessment will allow the evaluators to quickly make decisions about how to proceed with further assessments, if necessary.

Given the diversity of systems, products or services and objectives that research may have, it is necessary to select the property checklist instrument that best suits this purpose and, if necessary, adapt or create a new property checklist. The selection, adaptation or creation of a property checklist will depend on the judgment of the researchers.Given the lack of property checklists that consider the characteristics and needs of people with ASD, we have proposed our property checklist to evaluate systems, products or services used by

people with ASD [176]. This proposal takes as a theoretical basis our proposal of nine UX factors for people with ASD [11].

Table S presents a brief specification of the execution of the property checklist method (see appendix D), considering the inputs (elements necessary to start the execution of the method), execution steps (details on the execution of the evaluation method) and outputs (set of information and documents obtained after the execution of the method) that are relevant when implementing this evaluation method.

12.2.2.2 S2.2 Inspections

Second substage of the execution stage. The inspection substage considers three inspection methods: group-based expert walkthrough, perspective-based inspection, and heuristic evaluation. Next, each evaluation method will be explained in detail.

Group-Based Expert Walkthrough

The use of group-based expert walkthrough [152] allows us to identify potential usability problems, possible design improvements and solutions to these problems, through a group inspection carried out in conjunction with professionals "with practical experience" in the domain. The evaluation is based on the execution of a set of tasks–scenarios guided by a leader. The evaluation can be carried out using specific criteria of the domain under study, which are familiar to professionals who do not necessarily have knowledge about the UX. Consider that an expert with knowledge in both areas (UX/Usability and in the ASD domain) or a UX/Usability expert should take the lead role in the evaluation.

By using a group-based expert walkthrough inspection, we can easily include experts in the domain to the evaluation, as they do not need to have previous experience in executing UX/Usability evaluations. This can result in a greater amount of identified potential problems that are relevant for people with ASD and their characteristics.

Table T presents a brief specification of the execution of the group-based expert walkthrough method, considering the inputs, execution steps, and outputs (see appendix D) that are relevant when implementing this evaluation method.

Perspective-Based Inspection

An inspection method that focuses on the identification of specific usability problems through three main perspectives [153]. These perspectives are based on three types of users: novice, expert, and error-handling. Each evaluator assumes the role and point of view of a user and inspects the system, product or service under that user role, guided by a set of inspection questions for each perspective. Zhang et al. [153] recommends creating the inspection questions based on an HCI model, for which we recommend considering our nine UX factors [11], and the perspectives, which can include a novice and expert user with ASD.

When executing the method, ASD domain experts should support UX/Usability experts if possible. Domain experts may find it easier to put themselves in the shoes of a user with ASD and therefore find specific problems that UX experts may not recognize.Table ***U*** presents a brief specification of the execution of the perspective-based inspection method, considering the inputs, execution steps, and outputs (see appendix D) that are relevant when implementing this evaluation method.

Heuristic Evaluation

An inspection method that focuses on finding potential usability problems in systems, products, or services. This method [7] is based on the inspection of evaluators, who look for potential problems based on different sets of previously selected heuristics, while specifying their severity, frequency, and criticality. When using the heuristic evaluation method, the use of tasks and scenarios is optional, and its realization will depend on the investigators.

Consider evaluating the system, product, or service through one or more sets of heuristics that consider the characteristics and needs of people with ASD. These are our suggested heuristic sets:

- Khowaja and Salim [19] present a set of 15 system-specific heuristics for children with ASD. These 15 heuristics were created through the adaptation and extension of the Nielsen heuristics [177], based on a study of the characteristics of people with ASD.
- We are currently developing a set of heuristics to evaluate systems, products, or services for adults with ASD. For the creation of this set of heuristics, we followed the methodology proposed by Quiñones et al. [178], considering as a basis our proposal of nine UX factors for people with ASD [11].

Table V presents a brief specification of the execution of the heuristic evaluation method, considering the inputs, execution steps and outputs (see appendix D) that are relevant when implementing this evaluation method.

12.2.2.3 S2.3 User Tests

Once the inspections substage is finished or in parallel, the execution of at least one user test is required. Implementing tests with users' aims to find problems and measure the satisfaction of the participants after their interaction with the system, product, or service.

The user testing substage contemplates two methods: field observation and controlled observations. For both evaluation methods we recommend:

- Informing and instructing the user about the experiment, prior to carrying it out. Information and instructions must be clear and concise, prioritizing textual and/or visual communication.
- The interaction with the user, throughout the experiment, must consider the specific characteristics that the participant may present (e.g., not having any contact or physical proximity with people with ASD who may react negatively to this action).
- Having the consent of users or tutors (if necessary). Inform users and tutors that all information obtained will be treated anonymously.
- Keeping in mind throughout the experiment the dependence and autonomy of each of the participants. Sometimes the participants may require support from a tutor or a professional to help them.
- Obtaining the support of one or more tutors in case of any unforeseen event (if necessary). The tutor(s) can guide the user in the tasks to be carried out when necessary and/or assist the evaluators in identifying potential problems that may occur during the execution of the test.
- The investigator(s) should take on an observer role. Observers must not interfere during the experiment unless it is strictly necessary.

- Recording if the tutors or researchers have had to help the participants or interrupt the experiment, because the results obtained may be different or vary.
- Recording interactions with the system, product, or service through audiovisual recordings, always maintaining the anonymity of the user.
- Observers must record what they observed during the sessions in writing. We recommend recording the following information [179, 180]: (1) activity performed, (2) actions, events and behaviors observed by users, (3) possible cause of the problem, considering the characteristics of the user, (4) description of the user (to identify the user more quickly in the audiovisual record).

More details of each evaluation method are given below.

Field Observation

Field observation aims to obtain information from users and detect potential problems of the system, product, or service to be evaluated [151]. These potential problems are detected while observing the user interacting with the system, product, or service in a natural environment. When using the field observation method, we recommend:

- Scheduling one or more observation sessions for users. Each session must have an estimated duration.
- During sessions, users should always be in an environment that is familiar to them. It is for the same reason that it is recommended not to interrupt users' activities and not to distract users by including elements outside their usual environment.

Table W presents a brief specification of the execution of the field observation method, considering the inputs, execution steps, and outputs (see appendix D) that are relevant when implementing this evaluation method.

Controlled Observation

Controlled observation aims to identify potential problems that users may experience when interacting with the system, product, or service [151]. Controlled observation consists of the execution of guided activities, to eliminate the noise of the data obtained by including strict controls, such as the ordering of tasks, thus minimizing the possible effects of knowledge transfer between tasks and avoiding repetitive actions. When using the controlled observation method, we recommend:

- Recording the times that the participants have required to develop each task.
- Have a controlled environment, free from noise and visual distractions. If possible, make observations of the user in an appropriate laboratory.

Table X presents a brief specification of the execution of the controlled observation method, considering the inputs, execution steps, and outputs (see appendix D) that are relevant when implementing this evaluation method.

12.2.3 S3 Results Analysis Stage

In this stage the organization and analysis of the results obtained after the execution of the evaluation methods in the execution stage is performed. The purpose of this stage is to organize the information, generate quantitative and qualitative analysis, and create a UX

report that includes the main problems found, an analysis of these problems, as well as proposals for solutions to improve the UX of the product, system, or service.

As complementary material, Table Y is presented in appendix D, which describes what is needed, what to do and what is obtained as an output when implementing this stage. Additionally, a BPMN diagram of the steps to follow in this stage is presented in Figure H, available in appendix E.

12.2.3.1 S3.1 Grouping of Potential Problems

The first substage is the grouping of the problems obtained in the execution of the evaluation methods. These problems come from different methods and documents, and the result is a consolidated list of potential problems.

The other documents obtained as outputs in previous stages, such as task lists, preliminary and perception questionnaires, will be used in the analyses without prior grouping.

Consolidating the identified potential problems requires grouping the problems and then identifying the ones that come up repeatedly. To perform this task:

- Group the potential problems found in the inspection methods: heuristic evaluation, group-based expert walkthrough and perspective-based inspection. Create a consolidated list with the unique potential problems found in the lists obtained in these methods, including the values of severity, frequency, and criticality of each evaluator for each problem. Furthermore, consider modifying the problem titles and definitions if this helps improve the clarity, quality, and consistency of the final consolidated listing.
- In case of having repeated potential problems, each one should be merged into a single potential problem by averaging the values of severity, frequency, and criticality of the repeated problems, and then defining a consolidated title and definition for it.

12.2.3.2 S3.2 Quantitative Analysis

The quantitative information can come from different sources: through the results obtained in the execution of the property checklist method, consolidated list of potential problems, task lists, answers obtained in the perception questionnaires and answers to the preliminary questionnaires (demographic). To perform the quantitative analysis, analyze the data obtained in the following categories:

- *Results of the property checklist:* After verifying compliance with the items of the checklist used, the satisfaction percentage of the system, product or service can be obtained, as shown in Table S (see appendix D). As stated in our proposed property checklist [176] we recommend that evaluators rate each of the items on a scale of 1 to 5, from “Totally non-compliant” to “Totally compliant”. Establishing a scale from 1 to 5 will allow the researchers to determine the compliance of each item of the property checklist. In addition, if categories are established, as in our proposal [176], we recommend evaluating compliance with each of the proposed categories as a group. To analyze these results, we recommend calculating and graphing the percentages of compliance by category, as well as calculating the global percentage obtained after the evaluation, which will allow us to clearly know the results obtained

after completing the property checklist. A graphic way of visualizing the results obtained can be using radar charts [181].

- *List of potential problems:* For the potential problems obtained from the inspection methods grouped in substage S3.1, calculate the average and standard deviation of each of the severities, frequencies and criticalities assigned by each evaluator for each potential problem. A lower value of standard deviation may mean less discrepancies between evaluators; on the other hand, a higher value of standard deviation implies a notorious discrepancy between evaluators, so it is important to analyze these potential problems in detail. In addition, we recommend ordering the potential problems based on the average severity and criticality, to identify the potential problems that must be addressed with the highest priority.
- *List of tasks:* In the evaluation methods where the system, product or service is examined following a set of tasks, document the results and times required for the fulfillment of said tasks. From this, comparisons can be generated between the obtained results and times versus the expected results and times.
- *Preliminary questionnaire (demographic):* It is important to capture information from the participants and evaluators, such as their age, gender, experience in the use of similar systems, products, or services, among others. We recommend that for each of the evaluation methods the captured information be graphed, to identify patterns and facilitate its analysis.
- *System, product, or service perception questionnaire:* Organize and graph the information captured through Likert scales to obtain a graphic display of the perception of the participants and evaluators and thus facilitate its analysis and identify patterns.

12.2.3.3 S3.3 Qualitative Analysis

The qualitative information can come from different sources: the perception questionnaires obtained in the executed methods, the task lists, the observers' logs, and audiovisual and written records. To perform the qualitative analysis, consider for each result previously obtained:

- Ta*sk list:* For evaluation methods where the system, product or service is examined following a set of tasks, we recommend documenting the comments and the correct and incorrect actions carried out by the participants and/or evaluators.
- *Audiovisual and written records:* Organize and complement the written records obtained by the observers through the audiovisual records. These records can be based on the comments of the evaluators, as well as other aspects found when reviewing the captured audiovisual record.
- *Observer Logs:* Organize the information documented by the observers, such as comments and/or correct and incorrect actions carried out by the participants throughout the execution process of the evaluation method.
- *List of Comments and Recommendations:* Create a consolidated list that includes all the comments and recommendations identified through the perception questionnaires in each of the evaluation methods carried out, as well as those consolidated in the list of tasks, audiovisual records, and logs mentioned in the previous points. For this, it

is recommended to group the comments and/or recommendations of all the outputs into common and easy-to-understand categories, such as the proposed UX factors for people with ASD [11]. Repeated comments must be merged into a single new comment. Organizing and consolidating these comments and recommendations will make it possible to find common patterns, positive and negative aspects, as well as identify general and specific problems that have not been formally found through the methods.

12.2.3.4 S3.4 UX Report

After carrying out the detailed quantitative and qualitative analyses in the previous substages, the final stage of the methodology corresponds to the integration and interpretation of the results, which can be used to generate a detailed report on the UX in the system, product or service evaluated, highlighting the potential problems found and providing recommendations to improve the UX.

Considering the previous analyses, a single consolidated report on the UX of the system, product or service must be generated, which is considered the final output of the methodology to evaluate the UX in systems, products or services for people with ASD. To prepare this report, consider:

- We recommend that the UX evaluation report be organized first according to the evaluation methods executed, and then have a section for general results.
- *Results of methods:* Provide a consolidated analysis and interpretation of the information obtained in each of the experiments carried out with the selected methods, including potential problems found, conclusions and recommendations. Include interpretations of each of the graphs created with the information from the evaluations carried out.
- *Quantitative Analysis:* Include a section of general quantitative results where the potential problems found between the different evaluation methods are related, including, for example, most common potential problems, ranking of problems according to their general criticality, observations found when comparing the results of the methods and any other information that is relevant to improve the UX of the system, product, or service. The quantitative information can be classified and organized based on the established UX factors [11], or other criteria that the researchers deem convenient.
- *Qualitative Analysis:* Include a comments and qualitative analysis section, which presents an overview of the evaluation and includes the qualitative results analyzed in substage S3.3. For this analysis, it is important to highlight common patterns found in the comments of all the experiments, positive aspects, negative aspects, and any other information that is considered relevant to improve the UX of the system, product, or service. This analysis can be supported by the quantitative results of the report.
- *Recommendations and Proposed Solutions:* Include a section in the report where researchers present recommendations to solve the problems previously described in the report with a UX perspective, as well as recommendations that are considered relevant for future evaluations.

Once the UX report is completed, it can be used by the developers and/or stakeholders of the system, product, or service, to improve the UX of people with ASD by fixing the problems found and applying the recommendations provided.

13 METHOLOGY VALIDATION

Considering our preliminary proposal of the methodology [9], we have improved the methodology based on the opinions of three UX expert researchers. In this, each stage and substage have been detailed and restructured, and we included a new substage: S1.2 (Experiment Design). After consolidating these changes in a new version of the methodology, an expert judgment validation has been carried out, with 22 experts that have knowledge about UX/Usability, ASD, or both.

The experts' profiles include academic researchers, PhD students, computer scientists with UX/Usability expertise, and domain specific experts, such as speech therapists, psychologists, counselors, and educators with hands on experience working with people with ASD. Some of these experts have experience in both UX/Usability and ASD, and some have ASD themselves.

In the expert judgment validation, each participant has been given a specification document of the methodology, which includes a summarized version and a detailed version, and a survey which was created based on the proposal from Quiñones et al. [178]. The validation carried out is aimed at obtaining feedback from experts.

The survey has been divided into three sections.

1. *First section:* Learn about the background of the participating experts.
2. *Second section:* Evaluate the stages and substages of the methodology, using a five-level Likert scale (1—worst to 5—best) in four factors (F1, F2, F3 and F4):
    a. (F1) Usefulness: How useful do you consider each stage and substage of the methodology?
    b. (F2) Clarity: How do you rate the clarity of each stage and substage of the methodology?
    c. (F3) Ease of use: How easy would it be to implement each stage and substage of the methodology?
    d. (F4) Lack of Detail: Do you think that the stages and/or substages of the methodology need more detail or additional elements?
3. *Third section:* Know their opinions about the methodology, the stages and substages, which includes:
    a. Two questions (Q1 and Q2) focused on finding out their general opinion about the methodology, through a five-level Likert scale (1—worst to 5—best).
        i. (Q1) Use in future evaluations: If you had to evaluate the user experience in systems, products or services used by people with ASD, would you use our proposed methodology?
        ii. (Q2) Completeness: Do you think that the methodology covers all the aspects to be evaluated in systems, products or services used by people with ASD?

b. Five open questions focused on knowing their opinions and comments on the methodology, stages and substages.
    i. (O1): Would you remove or add any evaluation method proposed by the methodology? Which one(s) and why?
    ii. (O2): Would you change, add, or eliminate any aspect of a stage or substage of the methodology? Which one(s) and why?
    iii. (O3): Would you change, add, or eliminate any aspect of the evaluation methods considered in the proposed methodology? Which one(s) and why?
    iv. (O4): What aspects do you consider were not covered by the proposed methodology and should be included in the methodology to evaluate systems used by people with ASD?
    v. (O5): Do you have any additional comments and/or suggestions for the authors?

The following results were obtained from this survey.

13.1 Experts Background

To know about the backgrounds of the 22 experts, they have been asked about their previous knowledge about UX/Usability and ASD. As a result, we have obtained the following information:

- A total of 20 experts (90.90%) previously knew the concepts of UX/Usability.
- A total of 21 experts (94.45%) previously knew the ASD concept. From this 94.45%:
    - A total of eight experts (38.09%) mentioned that they have interacted with people with ASD, because they have relatives and/or are people diagnosed with ASD.
    - A total of 13 experts (61.90%) mentioned that they have taught, researched, or carried out experiments with people with ASD.

13.2 Quantitative Results

Table 19 shows the results obtained by each of the factors (F1–F4). The information obtained is analyzed below.

Table 19. Results for factors F1, F2, F3 and F4

	F1—Utility		**F2—Clarity**		**F3—Ease of Use**		**F4—Lack of Detail**	
	AVG	**SD**	**AVG**	**SD**	**AVG**	**SD**	**AVG**	**SD**
S1: Planning Stage	4.82	0.50	4.36	0.73	3.73	0.77	2.59	1.26
S1.1: Method Execution Planning	4.77	0.53	4.23	0.81	3.73	0.83	2.64	1.43
S1.2: Experiment Design	4.82	0.50	4.41	0.73	3.55	0.96	2.32	1.36
S1.3: Evaluators Selection	4.73	0.63	4.45	0.67	3.59	0.91	2.45	1.30
S1.4: Participants Selection	4.77	0.53	4.27	0.70	3.36	1.09	2.73	1.39
S2: Execution Stage	4.82	0.50	4.41	0.85	3.68	0.99	2.50	1.41
S2.1: Preliminary Evaluation	4.64	0.58	4.45	0.80	3.91	0.92	2.41	1.37
S2.2: Inspections	4.59	0.67	4.59	0.59	3.64	0.95	2.50	1.47
S2.3: User Tests	4.86	0.47	4.50	0.67	3.18	1.14	2.55	1.37
S3: Results Analysis Stage	4.91	0.29	4.41	0.85	4.00	0.93	2.18	1.33

S3.1: Quantitative Analysis	4.68	0.57	4.36	0.90	3.91	1.02	2.23	1.38
S3.2: Qualitative Analysis	4.77	0.43	4.36	0.85	4.00	0.93	2.18	1.30
S3.3: Integration of Results	4.82	0.50	4.23	0.97	3.68	0.89	2.32	1.43
	4.77		**4.39**		**3.69**		**2.43**	

It is important to mention that the methodology specification delivered to the experts only had three substages in the Results Analysis Stage. Considering the feedback from the experts, a new substage called "Grouping of potential problems" has been added, and substage S3.3 was renamed.

- (F1) Utility: The average utility of the methodology specification is high (4.77). Stage S3 (Results Analysis) is considered the most useful (4.91). The S2.2 substage (Inspections) is considered the least useful, however, its average is still high (4.59). The standard deviation is relatively low, ranging from 0.29 (stage S3) to 0.67 (stage S2.2). The standard deviation of stage S3 (Results Analysis) is the lowest of the four factors. The perceived usefulness of the methodology is high.
- (F2) Clarity: The average clarity of the methodology specification is high (4.39). Substage S2.2 (Inspections) is considered to have more clarity (4.59). Substages S1.1 (Method Execution Planning) and S3.3 (Integration of Results) are considered less clear (4.23). The standard deviation varies between 0.59 (substage S2.2) and 0.97 (substage S.3.3). The perceived clarity about the methodology is high. Considering the results obtained, the specification of the less clear perceived substages (S1.1 and S3.3) have been improved.
- (F3) Ease of use: The average ease of use of the methodology specification is moderate (3.69). Stage S3 (Results Analysis) and substage S3.2 (Qualitative Analysis) are considered to be the easier to use (4.00). Substage S2.3 (User Tests) is considered the most difficult to perform (3.18) and is the one with the highest standard deviation (1.14); experts commented that this stage has been considered the most difficult to carry out, due to the unforeseen events that may arise and the various profiles that people with ASD may have, and not necessarily due to the complexity of the substage specification. Standard deviations are relatively high, ranging from 0.77 (stage S1) to 1.14 (substage S2.3).
- (F4) Lack of Detail: The average lack of detail in the specification of the methodology is low (2.43). Due to the nature of the question, having a low average does not imply having obtained negative results. A high average means that the methodology is missing more details. The substage S1.4 (Selection of Participants) is the one with the highest average (2.73). Stage S3 (Results Analysis) and substage S3.2 (Qualitative Analysis) are the ones with the lowest average (2.18). Standard deviations are high, ranging from 1.26 (stage S1—Planning) to 1.47 (substage S2.2—Inspections). Expert opinions on the F4 factor are divergent/mixed.

The experts' perceptions of the factors are homogeneous, except for factor F4. Because substage S2.3 (User Tests) is perceived as having a high utility (4.86), with a low ease of use (3.18) and a comparatively high need for more detail (2.55), it is that its specification and ease of use have been improved. Additionally, greater detail has been

provided in the specification of substages S1.1 (Method Execution Planning) and S3.3 (Integration of Results) since they have been considered the least clear (4.23).

The results obtained in the two general questions (Q1 and Q2) on the methodology can be seen in Table 20.

Table 20. Results of questions Q1 and Q2

	Q1—Intention of Use in Future Evaluation	**Q2—Completeness**
Average	4.32	3.77
Standard Deviation	0.72	0.75

These results show that:

- The perception of the experts regarding the use of the methodology in future evaluations (Q1) is high (4.32). A total of 86% of the evaluators perceive that they would probably and/or definitely use the proposed methodology to evaluate systems, products or services used by people with ASD.
- The experts' perceptions regarding the completeness of the methodology (Q2) are relatively high (3.77). Experts emphasize that working with people with ASD is not an easy thing to do. A total of 77% of the evaluators declare that the methodology probably and/or definitely covers all the necessary aspects to evaluate systems, products or services used by people with ASD.

13.3 Qualitative Results

When experts have been asked if they would remove or add any evaluation methods to the proposed methodology (O1), most have mentioned that they would not remove or add any evaluation methods. They mention that the chosen methods are relevant to the context to be applied.

When experts have been asked if they would change, add, or remove any aspect of a stage or substage (O2), experts have provided various comments. Table 21 shows the comments of the experts, if the suggestion has been considered, and the justification or action performed.

Table 21. Results of questions O1 and O2

Comment	**Has Been Considered?**	**Justification/Action**
Previously train the participant with ASD, because eventually this new situation can cause stress.	No	The results of the tests with users can be biased if an induction is carried out beforehand. Emphasis has been placed on providing clear and concise instructions before and during the experiment.
Add more detail in the user testing substage.	Yes	Greater detail has been provided in substage S2.3, emphasizing the considerations that must be kept in mind when interacting with people with ASD.

Specify the number of participants, and if there will be a control group (with people without ASD) and/or an experimental group.	Yes	It has been detailed that the experiments should be carried out with people with ASD. It is recommended to have three or five participants with ASD [175].
Detail the faculties that the tutor will have during the tests with users.	Yes	It is detailed that the tutors must provide support to the participants, in case they are overwhelmed or do not understand the tasks to be carried out.

When the experts have been asked if they would change, add, or delete any aspect of the proposed evaluation methods (O3), the experts have mentioned various comments. Table 22 shows the comments of the experts, if the suggestion has been considered, and the justification or action performed.

Table 22. Results of question O3

Comment	Has Been Considered?	Justification/Action
Consider possible problems in the estimated times for each planned task.	Yes	The suggestion was added as something to consider when planning the user tests.
Document if the participants have answered the preliminary and/or perception questionnaires with the support of the tutors or autonomously.	Yes	This has been included in substage S2.3.

When the experts have been asked about what aspects they consider were not covered by the methodology and should be included (O4), the experts have mentioned various comments. Table 23 shows the comments of the experts, if the suggestion has been considered, and the justification or action performed.

Table 23. Results of question O4

Comment	Has Been Considered?	Justification/Action
Add a new stage, substage or product that details a possible "contingency plan".	No	We believe that the detail provided is sufficient as a basis for how to act in adverse situations.
Specify the link of the methodology and evaluation methods with the characteristics of people with ASD and/or proposed UX factors.	Yes	The suggestion has been included. The evaluation methods and the proposed UX factors [11] were selected/created based on the characteristics of people with ASD. It is recommended to particularize

		the instruments used in the evaluation methods for people with ASD.

When the experts have been asked if they have any additional comments and/or suggestions (O5), the experts have mentioned various comments. Table 24 shows the comments of the experts, if the suggestion has been considered, and the justification or action performed.

Table 24. Results of question O5

Comment	Has Been Considered?	Justification/Action
The number of evaluators should be as proposed by Nielsen and Landauer [175].	Yes	The suggestion has been included in substage S1.3, evaluators selection.
The methodology should consider the dependency and/or autonomy of people with ASD.	Yes	This suggestion has been included in S1 planning stage.

Expert feedback is positive. It is pointed out that the methodology is complete, replicable, and modern. It is highlighted that the methodology can help a better inclusion of people with ASD, and that it can be difficult to carry out tests with users with people with ASD. We have realized the need to modify the structure of stage S3 (Results Analysis Stage) and created sub-stages S3.1 (Grouping of potential problems) and S3.4 (UX Report), to provide better clarity for this stage. It should be noted that stage S3 (Results Analysis Stage) has only had a change in the structure and not in its content.

Considering the comments and suggestions provided by the evaluators, it has been possible to refine the proposed methodology, as presented in this document.

14 CASE STUDIES

The methodology for evaluating the user experience in systems, products or services used by people with ASD [12] was used to evaluate the UX in the PlanTEA mobile application and the website www.expedia.com [182]. The details of each case study conducted are presented below.

14.1 PlanTEA Application

With the collaboration of the CHICO research team of the University of Castilla-La Mancha and the AUTRADE association (Asociación Regional de Afectados de Autismo y Otros Trastornos del Desarrollo) in Spain, the proposed methodology [12] has been applied to the mobile application PlanTEA.

PlanTEA is a mobile application that allows children or adults with ASD to plan and anticipate attendance at medical consultations, as well as to facilitate communication with specialists through a communication notebook. PlanTEA was created and developed by the CHICO research team of the University of Castilla-La Mancha, Spain.

The following sections describe what was done and decisions made in each of the stages of the methodology [12] in the case study with the PlanTEA application.

14.1.1 S1 Planning Stage

Information about the PlanTEA application was collected, such as its characteristics, target users and limitations, which were essential for carrying out the substages of the planning stage. The collected results show that:

- *PlanTEA Characteristics:* Tablet application that helps to plan medical appointments and communicate with medical specialists through a communication notebook. Initially, the application requests the creation of an actor for the planner and user profiles, and also the assignment of a calming object designed for the user. Structurally, the mobile application is divided into two profiles: a planner and a user; the planner is in charge of assigning and scheduling medical appointments to the user, by means of pictograms that represent a series of steps to be followed before the medical appointment; and on the other hand, the user can interact and follow the steps represented in pictograms assigned by the planner, as well as interacting with the calming object and a communication notebook, which is intended to facilitate the user's communication with ASD and to facilitate the medical specialist.
- *Objective Users:* Children and adults with ASD who want to plan their medical appointments.
- *Limitations:* Mobile application designed for tablets with a resolution of 2560x1800. PlanTEA is not developed to be responsive and screen rotation is not allowed, which limits some actions on certain devices.

Considering these features, target users and limitations of the PlanTEA application, the substages were carried out.

14.1.1.1 S1.1 Method Execution Planning

In order to determine and select the evaluation methods to be used on the application, the purpose and scope of the UX evaluation were defined, and the available time and resources were determined.

- *Evaluation Objective:* Evaluate the perception of adults with level 1 ASD about the PlanTEA application.
- *Evaluation Scope:* Evaluate functionalities of creation and visualization of schedules, and interaction with the communication notebook and calming object.
- *Time and Resources:* There is flexibility of time and resources.

Considering the objective, scope, resources and time available, the decision was made to apply the following evaluation methods: property checklist, heuristic evaluation and controlled observation. For the execution of the selected evaluation methods, the following was considered:

- For the property checklist, our proposal for a checklist presented in previous works [176] was adapted (see appendix F). The proposed property checklist focuses on evaluating the UX for people with ASD.
- For the heuristic evaluation, the heuristics created by Castro et.al in its thesis document were used (see Table Z in appendix G). The set of heuristics selected focus on evaluating the UX of systems used by people with ASD.

14.1.1.2 S1.2 Experiment Design

Once the selected evaluation methods were defined, the experiment design document was created, containing the following information:

- The objective of each evaluation method performed is defined. For the inspection methods, property checklist and heuristic evaluation, the goal is to evaluate all the functionalities of the mobile application. For controlled observation, it is set to evaluate the creation and visualization of the programmed planification and to identify the calming object by the participant.
- For each activity to be performed, the expected results are defined.
- For the controlled observation, a scenario and two tasks were defined, which focused on the creation of a plan that helps the user to attend to be vaccinated against the flu. The tasks are focused on: (1) planning the medical appointment to get a flu shot in the planner profile and (2) identifying the calming object in the user profile. For more details on the scenario and planned tasks, see appendix H.
- The protocol is defined, which contains a set of documents necessary for the execution of the evaluation methods, that is:
    - *Confidentiality agreement:* Each participant in the controlled observation received a confidentiality agreement. This document was created according to the requirements of the Castilla-La Mancha University of Spain. It is important to mention that the confidentiality agreement expressly states that the information of the participants will not be disclosed and all recording will take place without showing faces and without registering the voices of the participants.

- *Preliminary Questionnaire and Perception Questionnaire:* For both inspection methods, a preliminary and perception questionnaire was created and provided to each evaluator. The questionnaires had 10 and 17 questions, for the preliminary and perception questionnaire, respectively. On the other hand, for the controlled observation method, a preliminary and perception questionnaire was provided to the participants, with a total of 8 and 17 questions respectively.
- *Observer logs:* At the time of controlled observation, two researchers recorded their observations of the participant's interactions with the application and the resulting behavior of PlanTEA.
- *Task list:* For controlled observation, a task list was given to each participant and to the researchers. In the list of tasks given to the researchers, the results and expected times were also detailed.

14.1.1.3 S1.3 Evaluators Selection

We contacted several experts with knowledge of UX, ASD and both via email. We had the help of 10 evaluators, 5 for each inspection method (property checklist and heuristic evaluation).

The experts' profiles include PhD students, computer scientists with UX/usability expertise, and domain-specific experts, such as psychologists and counselors with practical experience working with people with ASD. Two of the evaluators are professionals and workers of the AUTRADE association [183].

14.1.1.4 S1.4 Participants Selection

Through the AUTRADE association [183], we contacted 7 participants, users of said group, to conduct controlled observation. The 7 participants are people diagnosed with ASD level 1. In addition, there was the support of two AUTRADE professionals who took on the role of tutors, to provide support to the participants if needed.

14.1.2 S2 Execution Stage

Before performing the selected evaluation methods, the evaluators were: (1) explained the PlanTEA mobile application and its purpose, and (2) given a glossary explaining the concepts of UX, ASD, the main characteristics of the people with ASD, and an explanation of the evaluation to be performed and its steps.

Due to the available time, the evaluation methods were performed in the following order: (1) controlled observation, and (2) the two inspection methods (property checklist and heuristic evaluation) which were performed in parallel.

14.1.2.1 S2.1 Preliminary Evaluation

For the execution of the property checklist method [151], the 4 evaluators were emailed an Excel document with the adaptation of the proposed property checklist [176] (see appendix F) and the preliminary and perception questionnaires. The evaluators, who then interacted with the PlanTEA application, had to evaluate the compliance of each of the items presented in the property checklist by means of a scale of 1-5 (1: Not complied with at all - 5: Fully

Complied), and optionally provide comments/observations on each item. For further details on the execution of the property checklist method, see appendix I.

14.1.2.2 S2.2 Inspections

To perform the heuristic evaluation [7], the 5 evaluators were sent an Excel document to their e-mail with the following information: (1) list detailing the 16 heuristics created by Castro et. al, (2) spreadsheet to be completed by the evaluator with each potential problem found after interacting with the PlanTEA application and (3) preliminary and perception questionnaires. The evaluators were asked to identify at least 10 potential problems. For more details on the execution of the heuristic evaluation, see appendix I.

14.1.2.3 S2.3 User Tests

Controlled observation [151] was conducted with 7 participants with level 1 ASD at the AUTRADE association facilities. We had the support of two expert researchers in UX and ASD, and two professional experts in ASD from AUTRADE during the evaluation.

The participants read and agreed to the confidentiality agreement provided, answered the preliminary questionnaire, interacted with the PlanTEA application based on the scenario and tasks provided, and answered the perception questionnaire. For more details on the execution of the controlled observation, see appendix I.

14.1.3 S3 Results Analysis Stage

After the execution of each of the evaluations, property checklist, heuristic evaluation and controlled observation, the results obtained were organized and analyzed. As can be seen in appendix I, a summary of the results obtained by each evaluation method are presented below.

14.1.3.1 S3.1 Grouping of Potential Problems

To evaluate the UX of the PlanTEA application, only one evaluation method of the S2.2 Inspections substage was implemented, therefore the consolidated list of potential problems is the result of performing the heuristic evaluation. The list of potential problems is detailed in Table BB in appendix I.

14.1.3.2 S3.2 Quantitative Analysis

The information obtained from the evaluations carried out was analyzed. In general, the results obtained after quantitative analysis of the information are:

- *Results of the property checklist:* Taking into account the calculations detailed in the methodology proposal [12] and the answers of the evaluators, we can state that the percentage of satisfaction of the PlanTEA application is 68.5%. The highest percentages of satisfaction are in the predictability and attention retention categories, with 76.7% and 75% respectively. On the other hand, the lowest percentages of satisfaction are in the categories of engaging, structured and frustration-free, with 61.7%, 62% and 62.7% respectively.
- *List of potential problems:* Once the potential problems identified by the evaluators in the heuristic evaluation were consolidated, a total of 43 potential problems in the PlanTEA application were obtained as a result. After the evaluators assigned a

severity, frequency and criticality to each potential problem based on the scales presented in Table N, the averages and standard deviations of the scales for each potential problem found were calculated (see Table BB). The standard deviations obtained on the criticality of the problems show that 8 potential problems have values greater than 2.60, which means that the evaluators differ in their opinions. Additionally, the severity and criticality averages were arranged in descending order, and it can be stated/followed that: (1) a total of 5 potential problems obtained a criticality value greater than 7.0 on a scale of 0-8, and (2) a total of 18 potential problems obtained a severity value greater than 3.0 on a scale of 0-4.

- *List of tasks:* For the two tasks planned in the controlled observation, a time duration of 8 and 2 minutes was estimated, for the first and second tasks respectively. The results show that the expected results were underestimated, as the participants averaged about 18 min. However, we believe that the time given to the participants helped them not to become stressed and frustrated.
- *Preliminary Questionnaire (demographic) and Perception Questionnaire:* As can be seen in appendix I, the trends of the information obtained in each of the questionnaires delivered to the evaluators and participants were analyzed.

14.1.3.3 S3.3 Qualitative Analysis

The results obtained from the evaluations carried out were analyzed. In general, the results obtained after qualitative analysis of the information are:

- *List of tasks:* The comments and correct/incorrect actions performed by the participants during their interaction with the PlanTEA application in controlled observation were recorded and analyzed. For more details see appendix I.
- *Observer logs:* All the observations documented by the observers were organized. This information helped to supplement the information obtained in controlled observation.
- *Audiovisual and written records:* The records were organized and supplemented with the information recorded on video. Like the observer logs, this information helped to supplement the analysis obtained by each participant in the controlled observation. For more details see appendix I.
- *List of comments and recommendations:* The comments and recommendations obtained in appendix I have been organized and consolidated.

14.1.3.4 S3.4 UX Report

The UX report document was generated, where the analyzes and results obtained after the evaluation of the UX in the PlanTEA application are presented. The UX report is organized based on the evaluation methods applied. This report is the final output of the application of the methodology, and is presented in appendix I.

14.2 Expedia Website

As a second case study, the proposed methodology [12] has been applied to evaluate the UX on the website www.expedia.com [182]. Expedia is an online travel agency that allows you

to buy plane flights, rent accommodation, vehicles, cruises, vacation packages and amusement parks.

The following sections describe what was done and decisions made in each of the stages of the methodology [12] in the case study with the expedia.com website.

14.2.1 S1 Planning Stage

Information about the expedia website, its features, target users and limitations were collected:

- *Expedia Characteristics:* Website focused on searching and booking travel packages, flights, accommodation, vehicles, cruises, among others. The website offers inputs on its main page to search for different travel options through various filters and configurations. When creating travel packages, it is possible to search for accommodation, flights and vehicles, where each page has its own filters and design suitable for searching, filtering and configuring the corresponding parameters. At the end of a search, it is possible to make a reservation of all the selected elements.
- *Objective Users:* Users who want to plan a trip and include additional elements within a package.
- *Limitations:* The default language of the application may restrict the users using it, although this can be changed within the application.

Considering these features, target users and limitations of the Expedia website, the Planning Stage substages were carried out.

14.2.1.1 S1.1 Method Execution Planning

In order to determine and select the evaluation methods to be used on the website, the purpose and scope of the UX evaluation were defined, and the available resources and time were determined.

- *Evaluation Objective:* To evaluate the user experience when using the Expedia.com site, focusing on the characteristics of people with ASD.
- *Evaluation Scope:* Evaluate the functions of searching for travel packages, searching for accommodation and searching for flights in the desktop web version of expedia.com
- *Time and Resources:* There is flexibility of time and resources.

Considering the objective, scope, resources and time available, the decision was made to apply the following evaluation methods: property checklist, perspective-based inspection, group-based expert walkthrough and field observation. For the execution of the selected evaluation methods, the following were considered:

For the property checklist, our proposal for a checklist presented in previous works [176] was adapted (see appendix F). The proposed property checklist focuses on evaluating the UX for people with ASD.

For the perspective-based inspection, the perspectives were defined as novice user with ASD, expert user with ASD, and error handling user. To design the guidelines for each perspective, the suggested UX factors [11] were used.

14.2.1.2 S1.2 Experiment Design

Once the selected evaluation methods were defined, the experiment design document was created, containing the following information:

- The objective of each evaluation method performed is defined. For the inspection methods, property checklist, perspective-based inspection and group-based expert walkthrough, the objective is to evaluate the process of entering search parameters, accommodation search and flight search.
- For the group-based expert walkthrough and perspective-based inspection methods, a general scenario has been defined to guide the evaluators, which consists of searching for a flight package using specific parameters.
- For field observation, a simple scenario was defined to guide users, consisting of users planning their ideal trip.
- The protocol is defined, which contains a set of documents necessary for the execution of the evaluation methods, that is:
    - *Confidentiality Agreement:* Each field observation participant received a confidentiality agreement. This document expressly describes that the information of the participants will not be disclosed and all recordings will be without showing faces and only their screens will be recorded.
    - *Preliminary Questionnaire and Perception Questionnaire:* For inspection methods, a preliminary and perception questionnaire was created and provided to each evaluator. The questionnaires had 11 and 17 questions, for the preliminary and perception questionnaire respectively. On the other hand, for the field observation method, a perception questionnaire was provided to the participants, with a total of 16 questions.
    - *Observer logs:* At the time of field observation, a researcher recorded their observations related to the participant's interactions with the app and their behavior while using expedia.com.
    - *Task List:* For the perspective-based inspection and the group-based expert walkthrough, the evaluators were provided with a list containing the tasks to consider when interacting with the website.

14.2.1.3 S1.3 Evaluators Selection

To carry out the evaluations, experts with knowledge of UX, ASD and both were selected and contacted by email. In total, we had 11 experts: 4 for the property checklist, 4 for the group-based expert walkthrough, and 3 for the perspective-based inspection, with knowledge of UX, ASD and both areas. We also considered an additional lead evaluator for the group-based expert walkthrough.

14.2.1.4 S1.4 Participants Selection

For the field observation, we had the participation of 4 adults diagnosed with ASD level 1, who were contacted by email and social media.

14.2.2 S2 Execution Stage

Before carrying out the selected evaluation methods, the evaluators: (1) were explained the expedia.com website and its objective, and (2) were provided a glossary explaining the concepts of UX, ASD, the main characteristics of people with ASD, and an explanation of the evaluation to be performed and its steps.

Considering the time available, all the methods were performed in parallel. In the case of the group-based expert walkthrough, a date and time was agreed upon to meet with the evaluators in person to carry out this method.

14.2.2.1 S2.1 Preliminary Evaluation

For the execution of the property checklist method [151], the 5 evaluators were emailed an Excel document with the adaptation of the proposed property checklist [176] (see appendix F) and the preliminary and perception questionnaires. The evaluators, who then interacted with the website expedia.com, had to evaluate the compliance of each of the items presented in the property checklist on a 1-5 scale (1: Not complied with at all - 5: Totally Comply with), and optionally provide comments/observations on each item. For further details on performing the property checklist method, see appendix J.

14.2.2.2 S2.2 Inspections

To carry out the perspective-based inspection evaluation method [153], three perspectives were proposed: (1) Novice user with ASD, (2) Expert user with ASD, and (3) Error handling user with ASD. For each proposed perspective, there was an expert evaluator with knowledge of UX and ASD. Each evaluator was emailed an Excel document with the following information: (1) preliminary and perception questionnaire and (2) spreadsheet to be completed by the evaluator with each potential problem found after interacting with the website, in which the scenario, tasks, assessment scales (see Table N) and guide questions (see appendix K) are also detailed. The guide questions are intended to help the evaluators find potential problems on the expedia website. The evaluators were asked to identify at least 10 potential problems. For further details on the execution of the perspective-based inspection method, see appendix J.

To perform the group-based expert walkthrough evaluation method, 4 evaluators and an expert leader in UX and ASD were involved. The evaluation was conducted in person in a single session, where each evaluator had an excel document with the following information: (1) preliminary and perception questionnaire and (2) a spreadsheet to be completed by the evaluator with each potential problem found after the leader guided them through the website, detailing the scenario, tasks and assessment scales used (see Table N). The evaluation lasted approximately 3 hours. For further details on the execution of the group-based expert walkthrough method, see appendix J.

14.2.2.3 S2.3 User Tests

The field observation was conducted with 4 participants with ASD level 1 by video call. Participants freely explored the site as they searched for their ideal holiday, taking into account accommodation and flights. During the evaluation, a researcher observed the participant's interaction with the expedia.com website. The researcher did not interrupt the

participant and was attentive to any doubts or concerns expressed by the participant. The participants read and agreed to the confidentiality agreement, freely interacted with the expedia website and answered the perception questionnaire. For more details on the conduct of the field observation, see appendix J.

14.2.3 S3 Results Analysis Stage

After conducting each of the evaluations, property checklist, perspective-based inspection, group-based expert walkthrough and field observation, the results obtained were organized and analyzed. As can be seen in appendix J, the results obtained by each evaluation method are presented.

14.2.3.1 S3.1 Grouping of Potential Problems

We consolidated the potential problems identified in the perspective-based inspection and group-based expert walkthrough methods, in which a total of 34 and 72 potential problems were identified, respectively, together with the set of 39 potential problems found in the heuristic evaluation which was carried out by Ignacio Castro in his thesis.

We have evaluated and refined all repeated potential problems. A total of 10 repeated potential problems were found (for further details see Table PP and Table QQ of appendix J). After consolidating all the potential problems, including the repeated ones, we can conclude that a total of 135 potential problems have been identified, where 64, 28 and 33 potential problems are unique to the group-based expert walkthrough, perspective-based inspection and heuristics evaluation methods respectively.

14.2.3.2 S3.2 Quantitative Analysis

A set of information obtained from the evaluations carried out was analyzed. In general, the results obtained after quantitative analysis of the information are:

- *Results of the property checklist:* Taking into account the calculations outlined in the methodology proposal [12] and the responses of the evaluators, we can state that the percentage of satisfaction of the expedia.com website is 54.5%. The highest percentages of satisfaction are presented in the generalizable and predictable categories, with 68% and 60% respectively. On the other hand, the lowest percentages of satisfaction are shown in the adaptive and attention retention categories, with 28% and 50.7% respectively.
- *List of potential problems:* Once the potential problems identified by the evaluators in the evaluation methods, group-based expert walkthrough, perspective-based inspection, and heuristic evaluation were consolidated, a total of 135 potential problems were obtained on the expedia website. A total of 10 potential problems were repeated in the three evaluation methods. For the 10 potential repeated problems, the means and standard deviations of the severity, frequencies and critical points were calculated. The standard deviations obtained based on the criticality show that 5 potential problems have values greater than 1.25, which means that the evaluators differ in their opinions.
- *Preliminary questionnaire (demographic) and Perception Questionnaire:* As can be seen in appendix J, the trends of the information obtained in each of the questionnaires reported by the evaluators and participants were analyzed.

14.2.3.3 S3.3 Qualitative Analysis

A set of information obtained from the evaluations carried out was analyzed. In general, the results obtained after qualitative analysis of the information are:

- *List of tasks:* The comments and correct/incorrect actions performed by the participants during their interaction with the expedia website in the field observation were recorded and analyzed. For more details see appendix J.
- *Observer Logs:* All observations documented by observers are organized. This information helped to supplement the information obtained from the field observation.
- *Audiovisual and written records:* The records were organized and supplemented with the information recorded on video. Like the observer logs, this information helped to supplement the analysis obtained by each participant in the field observation. For more details see appendix J.
- *List of comments and recommendations:* The comments and recommendations obtained in appendix J have been organized and consolidated.

14.2.3.4 S3.4 UX Report

The UX report document was created, where the analysis and results obtained after the evaluation of the UX are presented on the expedia.com website. The UX report is organized based on the evaluation methods performed. This report is the final output of the application of the methodology, and is presented in appendix J.

14.3 Discussion

Using the evaluation methodology [12] made it easier to find multiple potential problems through the perspectives of different evaluators and users, whose professional and personal experiences give us different points of view regarding the user experience of a person with ASD when they interact with the application PlanTEA and the expedia.com website. Being able to rely on the support of professionals with experience in UX evaluations, as well as experts with applied experience with people with ASD, made it possible to generate a complete report on the main pain points in the application and website.

Applying the proposed methodology [12] to evaluate the UX in the PlanTEA app and the expedia.com website helped to find a variety of potential problems. The results obtained in the two case studies confirm that the different methods applied and proposals in the methodology complement each other, offering greater diversity and perspectives on the potential problems identified. By providing solutions for the main potential usability problems in a future version of PlanTEA and expedia will help ensure a better user experience for people with ASD.

15 CONCLUSIONES

Las personas con trastorno del espectro autista a menudo se comunican, interactúan, se comportan y aprenden de maneras muy diferentes a las de otras personas, incluyendo diferencias entre las personas con TEA, por lo que brindar una experiencia positiva es esencial al interactuar con personas con TEA.

Existen múltiples estudios dirigidos a apoyar a las personas con TEA a través de diversas tecnologías, donde los autores se enfocan mayormente en el desarrollo de habilidades sociales por sobre habilidades conceptuales y/o prácticas [4], habilidades que sin duda toman un papel fundamental en el día a día de las personas. Apoyar el desarrollo de estas habilidades sería muy beneficioso para las personas con TEA y su entorno.

Los estudios mencionan la importancia de aspectos como la experiencia del usuario, la usabilidad y la accesibilidad cuando se trabaja con personas con trastorno del espectro autista, sin embargo muchos de los métodos y/o instrumentos de evaluación utilizados en la literatura no son particularizados o no consideran las características de las personas con TEA. Las investigaciones no brindan suficiente detalle de las evaluaciones realizadas [4].

Sin duda, contar con un proceso formal facilitaría el uso y validación de la experiencia de usuario. Por ello, esta investigación tiene como objetivo establecer una metodología para evaluar la experiencia de usuario de personas con trastorno del espectro autista.

Para la creación de la metodología hemos seguido un proceso de siete etapas, durante las cuales hemos: (1) publicado una revisión sistemática de la literatura: “The Impact of Technology on People with Autism Spectrum Disorder: A Systematic Literature Review” [4]; (2) publicado el trabajo titulado: “Technology-Based Social Skills Learning for people with Autism Spectrum Disorder” [8] en la conferencia HCII 2020, la cual se centra en determinar cómo se diseñan los enfoques tecnológicos teniendo en cuenta las dificultades de las personas con TEA y su aprendizaje de habilidades sociales, con el objetivo de ayudar a los investigadores a diseñar nuevas intervenciones tecnológicas considerando las siete pautas de diseño propuestas; (3) publicado el artículo: “A Preliminary Methodology to Evaluate the User Experience for People with Autism Spectrum Disorder” [9] en la conferencia HCII 2021, la cual presenta una versión preliminar de la metodología propuesta; (4) publicado el artículo “User Experience Factors for People with Autism Spectrum Disorder” [11], en el que se propone un conjunto de 9 factores UX para sistemas, productos o servicios utilizados por personas con TEA; (5) publicado el artículo: “A Property Checklist to Evaluate the User Experience for People with Autism Spectrum Disorder” [176], en la conferencia HCII 2022, que presenta una adaptación del método de inspección property checklist para personas con TEA; y (6) publicado el artículo: “A Methodology to Evaluate the User Experience for People with ASD” [12], la cual presenta la versión final de la metodología propuesta y su validación.

Se realizaron dos validaciones a la propuesta preliminar de la metodología [9], donde expertos con conocimientos en UX/Usabilidad, condición TEA, y en ambas, nos han brindado comentarios y sugerencias. Se consideraron multiples comentarios y sugerencias realizadas, lo que dio como resultado la versión final publicada de la metodología [12].

Considerando los resultados de las dos validaciones realizadas (dos iteraciones en el proceso de creación, sección 9), podemos destacar que la metodología propuesta es percibida

por los expertos como útil, un aporte a la inclusión de las personas con TEA y, además, mencionan tener la intención de usarla en el futuro.

La metodología propuesta establece un proceso formal para evaluar la experiencia de usuario en sistemas, productos y servicios utilizados por adultos con TEA, que incluye métodos, instrumentos y procesos de evaluación que fueron seleccionados y adaptados de acuerdo a las características específicas de los usuarios. Utilizar la metodología propuesta con una adecuada selección o adaptación de instrumentos, puede ayudar a mejorar la satisfacción y percepción de las personas con TEA sobre el sistema, producto o servicio evaluado.

Creemos que esta propuesta metodológica contribuye a resolver la necesidad de un proceso formal para evaluar la UX de los sistemas, productos o servicios utilizados por las personas con TEA identificados en las primeras etapas de esta investigación. Mediante el uso de esta metodología, los investigadores podrán seguir un proceso validado que utiliza métodos e instrumentos específicos que fueron seleccionados y adaptados de acuerdo con las necesidades de las personas con TEA, y al identificar y abordar los posibles problemas de UX encontrados, la UX del sistema, producto o servicio se puede mejorar, ayudando así a proporcionar una experiencia positiva y gratificante para los usuarios con TEA.

En esta tesis hemos completado todos los objetivos definidos: “Determinar el uso de la tecnología con personas con trastorno del espectro autista”, “Identificar métodos adecuados para evaluar la experiencia de usuario de personas con trastorno del espectro autista”, “Formalizar una metodología para evaluar la experiencia de usuario de personas con trastorno del espectro autista”, y “Validar la metodología mediante juicio de expertos y estudios de casos”.

Consideramos que esta propuesta puede ser mejorada y complementada formalizando adaptaciones de todos los métodos de evaluación utilizados en la metodología, para que puedan ser utilizados de manera efectiva con personas con TEA.

Destacamos y agradecemos las instancias de colaboración entre miembros de las universidades PUCV, UMH y UCLM, así como el apoyo de la asociación AUTRADE, sus profesionales y los usuarios participantes de esta institución.

En trabajos futuros, tenemos previsto aplicar la metodología para evaluar la UX en nuevos casos de uso, con el apoyo de expertos con conocimientos en UX/Usabilidad y TEA.

16 CONCLUSIONS

People with autism spectrum disorder often communicate, interact, behave and learn in very different ways from other people, including differences between people with ASD, thus providing a positive experience is essential when interacting with people with ASD.

There are multiple studies aimed to support people with ASD through various technologies, where the authors are focused mostly on the development of social skills on conceptual and/or practical skills, skills that undoubtedly take a fundamental role in people's daily lives. Supporting the development of these skills would certainly be very beneficial for people with ASD and their environment.

Studies mention and declare the importance of aspects such as user experience, usability and accessibility when working with people with autism spectrum disorder, however many of the evaluation methods and/or instruments used in the literature are not particularized or do not consider the characteristics of people with ASD. The investigations do not provide enough detail of the evaluations carried out [4].

Without a doubt, having a formal process would facilitate the use and validation of the user experience. Therefore, this research aims to establish a methodology to evaluate the user experience for people with autism spectrum disorder.

For the creation of the methodology we have followed a seven-stage process, during which we have: (1) published a systematic literature review: “The Impact of Technology on People with Autism Spectrum Disorder: A Systematic Literature Review” [4]; (2) presented a paper: “Technology-Based Social Skills Learning for people with Autism Spectrum Disorder” [8] in the HCII 2020 conference, which is focused on determining how technological approaches are designed taking in consideration the difficulties of people with ASD and their learning of social skills, aiming to help researchers to design a new technological intervention by considering the seven design guidelines that we proposed; (3) presented a paper: “A Preliminary Methodology to Evaluate the User Experience for People with Autism Spectrum Disorder” [9] in the HCII 2021 conference, which presents a preliminary version of the proposed methodology; (4) published the article "User Experience Factors for People with Autism Spectrum Disorder" [11], in which a set of 9 UX factors for systems, products or services used by ASD people is proposed; (5) presented a paper: “A Property Checklist to Evaluate the User Experience for People with Autism Spectrum Disorder” [176], in the HCII 2022 conference, which presents an adaptation of the property checklist inspection method for people with ASD; and (6) published an article: “A Methodology to Evaluate the User Experience for People with ASD” [12], which presents the final version of the methodology and its validation.

Two validations were made to the preliminary proposal of the methodology [9], where experts with knowledge in UX/Usability, in the ASD condition, and in both, have provided us with comments and suggestions. Many of the comments and suggestions made were considered, resulting in the final published version of the methodology [12].

Considering the results of the two validations carried out (two iterations in the creation process, section 9), we can highlight that the proposed methodology is perceived by the experts as useful, a contribution to the inclusion of people with ASD and, furthermore, they mention having the intention of using it in the future.

The proposed methodology establishes a formal process to evaluate the user experience in systems, products and services used by adults with ASD, which includes evaluation methods, instruments and processes that were selected and adapted according to the specific characteristics of the users. Using the proposed methodology with an adequate selection or adaptation of instruments, can help to improve the satisfaction and perception of people with ASD about the system, product or service evaluated.

We believe that this methodology proposal contributes to solving the need for a formal process to evaluate the UX of systems, products or services used by people with ASD identified in the early stages of this investigation. By using this methodology, investigators will be able to follow a validated process that uses specific methods and instruments that were selected and adapted according to the needs of people with ASD, and by identifying and addressing the potential UX problems found, the UX of the system, product or service can be improved, thus helping in providing a positive and rewarding experience for users with ASD.

In this thesis we have completed all objectives defined: “Determine the use of technology with people with autism spectrum disorder”, “Identify appropriate methods to evaluate user experience for people with autism spectrum disorders”, “Formalize a methodology to evaluate the user experience for people with autism spectrum disorder”, and "Validate the methodology through expert judgment and case studies".

We consider that this proposal can be improved and complemented by formalizing adaptations of all the evaluation methods used in the methodology, so they can be effectively used with people with ASD.

We highlight and appreciate the instances of collaboration between members of the PUCV, UMH and UCLM universities, as well as the support of the AUTRADE association, its professionals, and the participating users from this institution.

In future work, we plan on applying the methodology to evaluate the UX on new use cases, with the support of experts with knowledge in UX/Usability and ASD.

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APPENDIX A

The elements of the BPMN notation used are described below.

Table A. Events Specification

Events		
Name	**Notation**	**Description**
Start		Notation that symbolizes the beginning of a process.
End		Notation symbolizing the ending of an ongoing process.

Table B. Activities Specification

Activities		
Name	**Notation**	**Description**
Task		Activity included in a process flow.
Sub-Process		Set of activities included in a process. It can be broken down into several detail levels called tasks.

Table C. Gateways Specification

Gateways		
Name	**Notation**	**Description**
Inclusive		Symbol representing the separation of the process flow into one or more flows. It can be used to indicate the execution of one or more activities at the same time.
Exclusive		Symbol representing the evaluation of a state, which can lead to different alternative routes, mutually exclusive, within the process flow. It is only possible to follow one path.

Parallel		Symbol indicating that it is possible to execute two or more process flows in parallel and synchronously.

Table D. Artifacts Specification

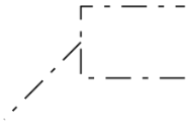
Artifacts		
Name	**Notation**	**Description**
Text Annotation		Symbol used to provide additional textual information.

Table E. Data Specification

Data		
Name	**Notation**	**Description**
Data Object		Symbol representing information that will be transformed by the process flow. It can represent documents that can be created and / or used by some activity.
Data Input		Symbol representing a document needed to start an activity.
Data Output		Symbol representing a document produced as a result of an activity.

APPENDIX B

Table F. Identified Learning Topics

Topic	Subtopic	Authors
Conceptual Skills	Language	Arciuli. J, Bailey. B. (2019) [39]
		Lin. C, Chang. S, Liou. W, Tsai. Y. (2013) [40]
		Wojciechowski. A., Al-Musawi. R. (2017) [41]
		Magaton. H, Bim. Silvia. (2017) [184]
		Mendonça. V, Coheur. L, Sardinha. A. (2015) [68]
		Wilson. C, Brereton. M, Ploderer. B, Sitbon. L. (2018) [185]
		Alvarado. C, Muñoz. R, Villarroel. R, et al. (2017) [186]
		Rasche. N, Pourcho. J, Wei. S, Qian. C.Z., Chen. V.Y. (2013) [187]
		Cunha. R.M., Barbosa. S.D.J. (2012) [188]
		Gomez. J, Jaccheri. L, Torrado. J.C, Montoro. G. (2018) [127]
		Khowaja. K, Salim. S.S, Al-Thani. D. (2018) [189]
		Khowaja. K, Salim. SS. (2019) [15]
		Khowaja. K, Al-Thani. D, Salim. SS. (2018) [47]
		Frutos. M, Bustos. I, Zapirain. B.G, Zorrilla. A.M. (2011) [190]
	Money	Caria. S, Paternò. F, Santoro. C, Semucci. V. (2018) [6]
	Colors	Tuğbagül Altan. N, Göktürk. M. (2018) [48]
	Math	Aziz. N.S.A, Ahmad. W.F.W, Hashim. A.S. (2016) [191]
		Naziatul. A.A, Wan. W.A, Ahmad. H. (2016) [70]
		Tashnim. A, Nowshin. S, Akter. F, Das. A.K. (2018) [49]
		Muñoz-Soto. R, Becerra. C, Noël. R., et al. (2016) [50]
		Aziz. N.S.A, Ahmad. W.F.W, Zulkifli. N.J.B. (2015) [192]
	Programming	Eiselt. K, Carter. P. (2019) [51]
		Schmidt. M, Beck. D. (2016) [52]
	Science	Eder. MS, Díaz. JML, Madela. JRS, Mag-usara. MU, Sabellano. DDM. (2016) [53]
Practical Skills	Healthcare	De Urturi. ZS, Méndez. A, García. B. (2011) [55]
		De Urturi. ZS, Méndez. A, García. B. (2012) [54]
	Daily Living	Pérez-Fuster. P, Sevilla. J, Herrera. G. (2019) [56]
		Fage. C, Pommereau. L, Consel. C, Balland. E, Sauzeon. H (2016) [57]
		Lee. D, Frey. G, Cheng. A, Shih. PC. (2018) [193]
	Transportation	McKissick. B, Spooner. F, Wood. C.L, Diegelmann. K.M. (2013) [58]
		De Los Rios. P. C. (2018) [14]
		Rector. K. (2018) [194]
Social Skills	Communication	Milne. M, Raghavendra. P, Leibbrandt. R, Powers. D.M.W. (2018) [59]

		Bringas. J.A.S, León. M.A.C, Cota. I.E, Carrillo. A.L. (2016) [195]
		Hussain. A, Abdullah. A, Husni. H, Mkpojiogu. E.O.C. (2016) [196]
		Bernardini. S, Porayska-Pomsta. K, Smith. T.J. (2014) [43]
		Tang H.H, Jheng. C.M, Chien. M.E, Lin. N.M, Chen. M.Y. (2013) [197]
		El-Seoud. M.S.A, Karkar. A.G, Al Ja'am. J.M, Karam. O.H. (2015) [198]
		Baldassarri. S, Passerino. L, Ramis. S, Riquelme. I, Perales. FJ. (2018) [199]
		Cabielles-Hernández. D, Pérez-Pérez. J.-R, Paule-Ruiz. M, Fernández-Fernández. S. (2017) [200]
		Ribeiro. PC, Raposo. AB. (2014) [60]
	Emotions	Romero. N.I. (2017) [61]
		Sturm. D, Kholodovsky. M, Arab. R, et al. (2019) [66]
		Papoutsi. C, Drigas. A, Skianis. C. (2018) [201]
		Lorenzo. G, Lledó. A, Pomares. J, Roig. R. (2016) [42]
		Leijdekkers. P, Gay. V, Wong. F. (2013) [202]
		Tinnunnem. S.G, Shah. G, Lahiri. U. (2017) [203]
		Harrold. N, Tan. C.T, Rosser. D, Leong. T.W. (2014) [73]
		Hyun. P.J, Abirached. B, Zhang. Y. (2012) [204]
		Castillo, T.A, Pérez de Celis. C, et al. (2016) [205]
		Almeida. LM, Silva. DPD, Theodório. DP, et al. (2019) [71]
		Cisnero. A.Q, Juárez-Ramírez. R., Figueroa. A.M. (2016) [206]
		Christinaki. E, Vidakis. N, Triantafyllidis. G. (2014) [62]
	Interpersonal Relationships	DiGennaro. F.D, Hyman. S.R, Hirst. J.M. (2011) [207]
		Boyd. L.E, Ringland. K.E, Haimson. O.L, Fernandez. H, Bistarkey. M, Hayes. G.R. (2015) [63]
		Muñoz. R, Morales. C, Villarroel. R, Quezada. A, De Albuquerque. V.H.C. (2019) [208]
		Rapp. A, Cena. F, Castald., R, Keller. R, Tirassa. M. (2018) [209]
		Sturm. D, Gillespie-Lynch. K, Kholodovsky. M. (2017) [210]
		Escobedo. L, Nguyen. D.H, Boyd. L.A, et al. (2012) [45]
		Hourcade. J.P, Bullock-Rest. N.E, Hansen. T.E. (2012) [64]
		Grossard. C, Grynspan. O, Serret. S, Jouen. A.L, Cohen. D. (2017) [211]
		Hughes. D.E, Vasquez E, Nicsinger. E. (2016) [212]
		Hani. H, Abu-Wandi. R. (2015) [213]
		Dehkordi. SR, Rias. RM. (2015) [214]

		Aziz. MZA, Abdullah. SAC, Adnan. SFS, Mazalan. L. (2014) [215]
		Jeekratok. K, Chanchalor. S, Murphy. E. (2014) [216]
General Skills	General	Backman. A, Mellblom. A, Norman-Claesson. E, Keith-Bodros. G, Frostvittra. M, Bölte. S, Hirvikoski. T. (2018) [5]
		Hong. E.R, Gong L.Y, Ninci. J, Morin. K, L.Davis. J, Kawaminami. S, Shi Y.G, Noro. F. (2017) [217]
		Still. K, May. R.J, Rehfeldt. R.A, Whelan R, Dymond. S. (2015) [218]
		Smith. K, Abrams. SS. (2019) [219]
		Cinquin. P.-A, Guitton. P, Sauzéon. H. (2019) [220]
		Jingga. F, Meyliana. Hidayanto. AN, Prabowo. H. (2019) [221]
		Constain. M. GE, Collazos O.C, Moreira. F. (2019) [222]
		Chen. J, Wang. G, Zhang. K, Wang. G, Liu. L. (2019) [72]
		Aziz. NSA, Ahmad. WFW, Hashim. AS. (2019) [223]
		Tsikinas. S, Xinogalos. S, Satratzemi. M, Kartasidou. L. (2018) [224]
		Çorlu. D, Taşel. Ş, Turan. S.G, Gatos. A, Yantaç. A.E. (2017) [225]
		Vallefuoco. E, Bravaccio. C, Pepino. A. (2017) [16]
		Tsikinas. S, Xinogalos. S, Satratzemi. M. (2016) [226]
		Wolff. M, Gattegno. M.P, Adrien. J.-L, Gabeau. C, Isnard. P. (2014) [227]
		Marchett. E, Valente. A. (2015) [228]
		Alarcon-Licona. S, Loke. L, Ahmadpour N. (2018) [229]
		Sorce. S, Gentile. V, Oliveto. D, Barraco. R, Malizia. A, Gentile. A. (2018) [44]
		Mazon. C, Fage. C, Sauzéon. H. (2019) [230]
		Goosen. L. (2019) [231]
		Santarosa. L.M.C, Conforto. D. (2016) [69]
		Rahman. M.R, Naha. S, Roy. P.C, et al. (2011) [232]
		Silva Sandez. G, Rodriguez Miranda. F.P. (2018) [233]
		Silva. S.D, Neto. F.M.M, De Lima. R.M, De Macedo. F.T, Santo. J.R.S, Silva. W.L.N. (2017) [46]
		Kamaruzaman. N.N, Jomhari. N. (2015) [67]
		Tsikinas. S, Xinogalos. S. (2019) [234]
		Helmi Adly. MN, Faaizah. S, Naim. CP. (2013) [235]
		Boucenna. S, Narzisi., A, Tilmont. E, et al. (2014) [236]
		Hulusic. V, Pistoljevic. N. (2012) [65]

Table G. Identified User Experience Concepts

Authors	Identified Concepts
Backman. A, Mellblom. A, Norman-Claesson. E, Keith-Bodros. G, Frostvittra. M, Bölte. S, Hirvikoski. T. (2018) [5]	Usability

Romero. N.I. (2017) [61]	Accessibility
Sturm. D, Kholodovsky. M, Arab. R, et al. (2019) [66]	Usability
Constain. M. GE, Collazos O.C, Moreira. F. (2019) [222]	Usability, accessibility
Muñoz. R, Morales. C, Villarroel. R, Quezada. A, De Albuquerque. V.H.C. (2019) [208]	Usability
Caria. S, Paternò. F, Santoro. C, Semucci. V. (2018) [6]	Usability, accessibility
Milne. M, Raghavendra. P, Leibbrandt. R, Powers. D.M.W. (2018) [59]	Usability
Wojciechowski. A., Al-Musawi. R. (2017) [41]	Usability
Vallefuoco. E, Bravaccio. C, Pepino. A. (2017) [16]	Usability
Naziatul. A.A, Wan. W.A, Ahmad. H. (2016) [70]	Usability
Sorce. S, Gentile. V, Oliveto. D, Barraco. R, Malizia. A, Gentile. A. (2018) [44]	Usability, accessibility
De Los Rios. P.C. (2018) [14]	Usability, accessibility
Mendonça. V, Coheur. L, Sardinha. A. (2015) [68]	User experience
Rector. K. (2018) [194]	Accessibility
Tang H.H, Jheng. C.M, Chien. M.E, Lin. N.M, Chen. M.Y. (2013) [197]	Usability, accessibility, user experience
Muñoz-Soto. R, Becerra. C, Noël. R., et al. (2016) [50]	Usability, accessibility, user experience
Santarosa. L.M.C, Conforto. D. (2016) [69]	Usability, accessibility
Khowaja. K, Salim. SS. (2019) [15]	Usability
Almeida. LM, Silva. DPD, Theodório. DP, et al. (2019) [71]	Usability, accessibility
Lee. D, Frey. G, Cheng. A, Shih. PC. (2018) [193]	Usability, accessibility, user centered
Cabielles-Hernández. D, Pérez-Pérez. J.-R, Paule-Ruiz. M, Fernández-Fernández. S. (2017) [200]	Accessibility
Schmidt. M, Beck. D. (2016) [52]	Usability
Eder. MS, Díaz. JML, Madela. JRS, Magusara. MU, Sabellano. DDM. (2016) [53]	Usability

Table H. Identified Game Elements

Authors	Game Elements Referenced
Romero. N.I. (2017) [61]	Points, intrinsic rewards
McKissick. B, Spooner. F, Wood. C.L, Diegelmann. K.M. (2013) [58]	Achievement, levels
Lin. C, Chang. S, Liou. W, Tsai. Y. (2013) [40]	Points
Boyd. L.E, Ringland. K.E, Haimson. O.L, Fernandez. H, Bistarkey. M, Hayes. G.R. (2015) [63]	Points, levels, rewards, collaboration
Sturm. D, Kholodovsky. M, Arab. R, et al. (2019) [66]	Points, levels, rewards, narrative, collaboration
Muñoz. R, Morales. C, Villarroel. R, Quezada. A, De Albuquerque. V.H.C. (2019) [208]	Levels
Chen. J, Wang. G, Zhang. K, Wang. G, Liu. L. (2019) [72]	Points, levels, rewards

Aziz. NSA, Ahmad. WFW, Hashim. AS. (2019) [223]	Levels
Caria. S, Paternò. F, Santoro. C, Semucci. V. (2018) [6]	Levels
Milne. M, Raghavendra. P, Leibbrandt. R, Powers. D.M.W. (2018) [59]	Feedback, rewards
Sturm. D, Gillespie-Lynch. K, Kholodovsky. M. (2017) [210]	Levels, collaboration
Vallefuoco. E, Bravaccio. C, Pepino. A. (2017) [16]	Feedback
Bringas. J.A.S, León. M.A.C, Cota. I.E, Carrillo. A.L. (2016) [195]	Points, levels, feedback, rewards
Lorenzo. G, Lledó. A, Pomares. J, Roig. R. (2016) [42]	Avatars
Bernardini. S, Porayska-Pomsta. K, Smith. T.J. (2014) [43]	Avatars
Sorce. S, Gentile. V, Oliveto. D, Barraco. R, Malizia. A, Gentile. A. (2018) [44]	Avatars
Magaton. H, Bim. Silvia. (2017) [184]	Levels
Tashnim. A, Nowshin. S, Akter. F, Das. A.K. (2018) [49]	Rewards
Alvarado. C, Muñoz. R, Villarroel. R, et al. (2017) [186]	Points, levels
Muñoz-Soto. R, Becerra. C, Noël. R., et al. (2016) [50]	Points, levels
Escobedo. L, Nguyen. D.H, Boyd. L.A, et al. (2012) [45]	Points, levels, rewards
Harrold. N, Tan. C.T, Rosser. D, Leong. T.W. (2014) [73]	Points, levels, rewards
Khowaja. K, Salim. SS. (2019) [15]	Achievement, points, levels, rewards
Almeida. LM, Silva. DPD, Theodório. DP, et al. (2019) [71]	Points, levels, avatars, feedback
Lee. D, Frey. G, Cheng. A, Shih. PC. (2018) [193]	Rewards
Baldassarri. S, Passerino. L, Ramis. S, Riquelme. I, Perales. FJ. (2018) [199]	Points, levels
Hughes. D.E, Vasquez E, Nicsinger. E. (2016) [212]	Achievement, points, avatars
Schmidt. M, Beck. D. (2016) [52]	Team
Eder. MS, Díaz. JML, Madela. JRS, Mag-usara. MU, Sabellano. DDM. (2016) [53]	Levels
Dehkordi. SR, Rias. RM. (2015) [214]	Points, levels, rewards
Ribeiro. PC, Raposo. AB. (2014) [60]	Levels, collaboration
De Urturi. ZS, Méndez. A, García. B. (2012) [54]	Levels, avatars

APPENDIX C

Table I. UX Factors Specified for ASD

Morville UX Factor	Characteristics/Difficulties/Affinities of People with ASD	UX Factor for People with ASD
Useful	• Students on the autism spectrum enjoy playing games, as this provides a safe environment [2]. • People with ASD find real social interactions to be stressful and intimidating because they are unpredictable [43] as well as being initially frightening, challenging, and even undesirable • People with ASD experience difficulties with developing social skills [81], which leads to social isolation [82].	• The system should provide a safe environment to help users fulfill their needs. • The content should be predictable and should not be stressful or intimidating (frightening, challenging, and undesirable) when socializing, thus facilitating social interaction needs.
Usable	• People with ASD have difficulties when generalizing skills to real-world contexts [26]. • People with ASD tend to be more susceptible to experiencing depression and frustration [27]. • People with ASD find real social interactions to be stressful and intimidating because they are unpredictable [43] as well as being initially frightening, challenging, and even undesirable. • People with ASD have a tendency to engage in visual and structured thinking [24]. • People with ASD exhibit hyper- or hypo-reactivity to sensory input or an unusual interest in sensory aspects of the environment [1].	• The system should be familiar enough and similar enough to real life to facilitate generalizing skills. • The system should be simple so it is easy to understand and does not cause frustration or demotivation. • The system should be predictable so that it is not stressful or intimidating. • The system should be easy to use by focusing on providing visual and structured elements. • Learning through interaction with system should not be frightening. • Elements of the system should be measured/controlled to not cause hyper- or hypo-reactivity to sensory inputs, such as visual, auditory, and tactile inputs.
Desirable	• People with autism spectrum disorder (ASD) tend to enjoy themselves and be engaged when interacting with computers, as these interactions occur in a safe and trustworthy environment [4].	• Design elements should evoke emotions and appreciation, ensuring a safe and trustworthy environment through technology.

	• Students on the autism spectrum enjoy playing games, as this provides a safe environment [2]. • People with ASD have a tendency to engage in visual and structured thinking [24]. • People with ASD have difficulties when generalizing skills to real-world contexts [26].	• Visual aesthetics should be attractive and focused to appeal to the structured and visual thinking of users ASD. • Visual aesthetics, audio, and touch inputs should reflect real life to facilitate interpretation and the generalization of skills.
Findable	• Stereotyped or repetitive motor movements, use of objects, or speech [1]. • Insistence on sameness, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior [1]. • People with ASD have a tendency to engage in visual and structured thinking *[24]*. • Patterns of restricted or repetitive behaviors that characterize people with ASD leading to problems with adapting to novel environments [1].	• Information and navigational setup should be structured and consistent to adapt to the inflexible and structured thinking of users with ASD. • The users should be able to quickly find information and solutions to any problem to facilitate adaptation to novel environments and avoid frustration.
Accessible	• The delay of fine motor skills development causes difficulties with interaction [25]. • People with ASD show persistent deficits in social communication and social interaction across multiple contexts [1]. • People with ASD exhibit deficits in social–emotional reciprocity [1]. • People with ASD exhibit deficits in nonverbal communicative behaviors used for social interaction [1]. • People with ASD exhibit deficits in developing, maintaining, and understanding relationships [1].	• The system should be designed to be easy to use, enjoyable, and engaging for users with and without ASD. • The system should consider deficits in social interaction when including any social elements in its design. • The system should consider deficits in fine motor skills during interactions through any input device.
Credible	• People with ASD find real social interactions to be stressful and intimidating because they are unpredictable [43] as well as being initially frightening, challenging, and even undesirable.	• The system should provide a non-stressful, non-frustrating, and predictable environment to create a trustworthy context for users. • The system should comply with skills learning functions.

	• People with ASD tend to be more susceptible to experiencing depression and frustration [27].	
Valuable	• People with ASD have difficulties when generalizing skills to real-world contexts [26].	• The system should have perceived value for creators and real-life value for skills learning through generalization to real-world contexts.

Table J. ASD Guidelines and Recommendations Provided in the Literature

Title	Guidelines
Design Guidelines for Serious Games Targeted to People with Autism [138].	Feedback
	Customization and personalization
	Graphical interface
	Increasing game difficulty
	Repetition
	Motivators
	Participatory design
Nature as a Healer for Autistic Children [149].	Visual principle as a therapeutic tool
	Design elements as a therapeutic tool
	Physical landscape feature as a therapeutic tool
	Landscape resources and materials as a therapeutic tool
	Design guidelines
Designing and Evaluating Touchless Playful Interaction for ASD Children [136].	General guidelines
	Goal-specific guidelines: Motor skills
	Goal-specific guidelines: Cognitive skills
	Goal-specific guidelines: Social skills
Design Considerations for the Autism Spectrum Disorder-Friendly Key Stage 1 Classroom [150].	Threshold and entrance
	Cloakroom provision
	Sight lines entering the classroom
	Visual timetable
	High-level glazing
	Volumetric expression
	Control
	Access to classroom external play
	Access to school playground
	Quiet room
	Toilet provision
	Kitchen
	Floor area
	Storage
	Computer provision
	Workstations
	Minimize delay to interaction
	Real-time is fun

Designing Visualizations to Facilitate Multisyllabic Speech with Children with Autism and Speech Delays [145].	Child customization
	Dynamic computer correction
	Robust microphone setup
	Competence of the child
	Physical interaction
Assessing the Target' Size and Drag Distance in Mobile Applications for Users with Autism [137].	Minimum pixel size
Empowering Children with ASD and Their Parents: Design of a Serious Game for Anxiety and Stress Reduction [140].	Customizability
	Evolving tasks
	Unique goal
	Instructions
	Reward
	Repeatability
	Transitions
	Minimalistic graphics
	Clear audio
	Dynamic stimuli
	Serendipity
	Sound and music
	Background story
	Language and text
	Actions and goals
	Simplicity
	Scoring
Towards a Serious Games Design Framework for People with Intellectual Disability or Autism Spectrum Disorder [139].	Pedagogy
	Learning content and game mechanics
	Evaluation
Development of the AASPIRE Web Accessibility Guidelines for Autistic Web Users [146].	Physical accessibility
	Intellectual accessibility
	Social accessibility
AutismGuide: Usability Guidelines to Design Software Solutions for Users with Autism Spectrum Disorder [147].	General usability principles
	Nonfunctional requirements
	Functional requirements for caregivers/partners
	Adaptability
	Guidance
	Workload
	Compatibility
	Explicit control
	Significance of codes
	Error management
	Consistency
Towards Developing Digital Interventions Supporting Empathic Ability for Children with Autism Spectrum Disorder [141].	Graphical layout
	Navigation and structure
	Language
	Interaction

Creating Individualized Computer-Assisted Instruction for Students with Autism Using Multimedia Authoring Software [142].	Learning styles of individual students
	Independent responding
	Social interaction
	Responsivity
	Age appropriateness
	Overlearning
	Natural environment
	Generalization
	Communication attempts
	Student choice of stimulus materials
	Cognitive ability
	Task variation
	Over-selectivity
	Vary the reinforcers
	Multiple cues
	Prompts
	Maximal use of technology
	Data collection as a design feature
Learning Styles of Autistic Children [144].	The authors do not detail specific categories for 18 guidelines and/or recommendations
Understanding Natural Language [143].	The authors do not detail specific categories for eight guidelines and/or recommendations
Heuristics to Evaluate Interactive Systems for Children with Autism Spectrum Disorder (ASD) [19].	Visibility of system status
	Match between system and the real world
	Consistency and standards
	Recognition rather than recall
	Aesthetic and minimalist design—minimize distraction and keep design simple
	User control and freedom
	Error prevention
	Flexibility and efficiency of use
	Help users recognize, diagnose, and recover from errors
	Help and documentation
	Personalization of screen items
	User interface screens of the system
	Responsiveness of the system
	Track user activities, monitor performance, and repeat activity
	Use of multimodalities for communication
Technology-Based Social Skills Learning for People with Autism Spectrum Disorder [8].	Structured and predictable learning environment
	Generalization to daily life
	Learning dynamics: individual and collaborative
	Engagement through activity cycles and game elements

	Error managing
	Mixed activities
	No-touch and hybrid interfaces

Table K. ASD Guideline and Recommendation Categorization

Category	Subcategory	Definition	Sources
Engagement	Feedback	"Software solution designed for users with ASD must (…) provide immediate feedback on the user's actions (the response time must be as short as possible)." [147]	[8, 19, 138, 144, 147, 149]
	Rewards	"Offering a reward after a good performance, increases the child's motivation, engagement and implicitly improves skills." [140]	[8, 136, 140]
	Motivation	"Motivation encourages users to achieve objectives and develop expected behaviors. This motivation can be extrinsic and intrinsic." [8]	[8, 136, 138, 139, 142]
Task Interaction	Task Design	"Software solutions designed for users with ASD must take account of their various characteristics (habits, skills, age, expectations, etc.) and adapt the tasks, navigation, layout, etc., accordingly." [147]	[136, 140, 142, 144, 147]
	Evolution	"Increasing levels of motor or cognitive complexity should be incorporated in the game." [140]	[8, 136, 138, 139, 140]
	Simple and Concise	"Make content as concise as possible without sacrificing precision and specificity, to reduce cognitive burden." [146]	[146]
	Instructions	"The software should speak directions to the student in a clear and direct manner." [142]	[19, 136, 140, 141, 142, 146, 147]
	Memory Load	"Minimise 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 screen to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate." [19]	[19]
	Goal	"There should be one unique explicit goal to reach within a gaming session." [140]	[136, 139, 140]
Generalizable	Generalizable	"The system should speak the users' language, with words, phrases and	[8, 19, 142, 146]

		concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order." [19]	
Personalization and Customization	Personalization	"The system should allow personalisation of screen items based on needs, abilities and preferences of an individual child. Screen items should be large enough for children to read and interact with. It should also allow them to change various settings of system background, font, colour, screen size and others." [19]	[19, 136, 138, 139, 140, 145, 146, 147]
	Customization	"Software solutions designed for users with ASD must react to the context and these users' needs and preferences." [147]	[8, 19, 136, 140, 142, 144, 145, 146, 147, 149]
Senses	Layout	"Use the simplest interface possible for ease of understanding." [146]	[137, 141, 142, 143, 144, 146, 147, 149, 150]
	Graphics	"Graphics should be aesthetically pleasing, but always functional. Irrelevant elements might form a distraction and can lead to loss of attention. Too many visual or colors might trigger anxiety as it might be difficult for the child to interpret individual elements." [140]	[136, 138, 140, 141, 142, 144, 146, 147, 149]
	Language	"Any language and text present in the game should be free from figures of speech and as clear as possible" [140]	[140, 141, 144, 146, 147]
	Workload	"Software solutions designed for users with ASD must promote their perception, concentration, attention, memory, etc. They must therefore (…) avoid users being exposed to large numbers of functionalities, images, animations, etc., at any one time" [147]	[19, 139, 144, 147, 150]
	Audio	"Children with ASD can be sensitive to audio stimuli, which can create extra stress. Sound or music can be used to provide feedback on actions, to complement a visual reward or during a transition phase in the game." [140]	[136, 140, 142, 143, 144, 147]

	Physical	"Children want to touch everything. Touch is an easy-to-understand interaction. Therefore, design systems that not only respond to touch, but provide meaningful feedback for those interaction" [145]	[8, 136, 143, 145, 147, 149]
Structure, Repeatability, and Predictability	Structured	"Children with autism thrive in a structured environment. Establish a routine and keep it as consistent as possible." [144]	[8, 141, 143, 144, 146]
	Repetition	"Children with autism generally enjoy repetition and may engage in repetitive activity to the detriment of other activities." [143]	[136, 140, 142, 143, 144, 147, 149]
	Consistency	"The system should use clear and consistent language so that users do not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions in the design for consistency." [19]	[19, 136, 140, 141, 144, 146, 147]
	Predictability	"When working with people with autism spectrum disorder, it must be ensured that we provide a structured and predictable learning environment, since people with ASD have restricted and repetitive patterns of behavior, interests or verbal and non-verbal activities." [8]	[8, 136, 140, 141, 143, 144, 147]
	Control	"Software solutions designed for users with ASD must ensure that they always have control (e.g., pause, restart) over the computer processing." [147]	[143, 144, 147]
Attention and Timing	Attention Retention	"Providing animations or music helps to retain the child's attention. If there are no visual or auditive stimuli, the child might lose his/her attention. A prolonged static visual, on the other hand, might trigger unwanted behavior, such as stereotyped movements or motor rigidity, e.g., gazing at a static image on the screen." [140]	[136, 140, 142, 143, 145]
	Distraction	"The time of restarting a session or switching from one level to the next one must be minimized, to reduce the	[19, 136, 140, 143, 147]

		risk of a child's loss of concentration during the transition." [136]	
	Timing	"When designing software for children, ensure that when the child wants to engage, and the software is ready to respond and delays are minimized." [145]	[19, 140, 142, 144, 145]
External Agents	Location	"Select a location with the least amount of distractions possible. high-pitched or humming noise, adjacent traffic and noise from air conditioning compressors can be overwhelming." [149]	[136, 149, 150]
	People	"It is important to include special education teachers and professionals in the design phase of a SG. They can define the requirements, goals and learning objectives of the game." [139]	[138, 139, 142, 147]
	Hardware	"Software solutions designed for users with ASD must … have a long lifespan (robust hardware, without frequent replacement need, etc.) and high availability (independent of Wi-Fi and available via Web, tablet and laptop)" [147]	[19, 142, 147]
Error Management	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." [19]	[8, 19, 143, 146, 147]
	Recognition	"(…) provide good-quality error messages (clear, multimedia message: video, audio, animation) and avoid indicating success or failure solely by means of a colour or a facial expression (frown, smile, etc.)" [147]	[19, 142, 147]
	Recovery	"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. The system should allow users to move from one part to another and provide the facility	[19, 147]

		to repetitively perform activities." [19]	

APPENDIX D

Table L. Planning Stage Specification

S1: Planning Stage Plan UX evaluations to be performed. Find experts, participants, and tutors.	
What do I need to get started?	• Select a specific system to evaluate UX.
What to do?	• Collect information about the system. • Selection of evaluation methods to be performed. • Identify and describe goals, protocols, scenarios, tasks and expected results of the evaluation. • Selection of participants with ASD *, tutors **, UX/Usability experts and ASD domain experts. * Participants must be within the objective users of the system, product, or service to be evaluated. ** Considering the dependence and autonomy of the participants, we recommend having the support of tutors or evaluators who can help the participants with problems or questions.
What is obtained?	• ① System, product, or service information. • ② List of methods to execute. • ③ Experiment Design Document. • ④ List of evaluators. • ⑤ List of participants.

Table M. Method Execution Planning Specification

S1.1 Method Execution Planning Selection and planning of methods to be executed.	
What do I need to get started?	• ① System, product, or service information.

What to do?	• Collect system, product, or service information.
	• Define objective and scope of the UX evaluation.
	• Select the evaluation methods to be carried out based on the objective, scope, resources, and available time. It is recommended that:
	  ○ If there are no time and resource constraints, it is suggested to perform all the methods proposed in the methodology (Figure 9).
	  ○ If there are time and resource constraints, it is recommended to follow the simplified sequence: property checklist, heuristic evaluation and field observation.
	Otherwise, select the methods to be performed according to the time and resources available, considering the complexity of each method (see S1.1 Method Execution Planning).

What is obtained?	• ② List of methods to execute.

Table N. Rating Scales of Problems Detected

Rating Scale	**Description**	**Range**	**Scale**
Severity	Scale that evaluates how detrimental the potential problem is to the use of the system.	0–4	(4) Catastrophic problem; (3) major problem; (2) minor problem; (1) cosmetic problem; (0) it is not a problem

Frequency	Scale that evaluates the occurrence of the problem during use of the system.	0–4	(4) >90%; (3) 51–90%; (2) 11–50%; (1) 1–10%; (0) <1%
Criticality	Sum of the assigned severity and frequency, which represents the level of criticality of the problem.	0–8	

Table O. Experiment Design Specification

S1.2 Experiment Design Design and specify the experiments to be performed.	
What do I need to get started?	• ① System, product, or service information. • ② List of methods to execute.
What to do?	• Collect system, product, or service information. • Define the evaluation objective(s) for each method to be carried out. • Define expected results to be obtained in each evaluation. • Scenario creation. • Task set creation. • Protocol creation. The protocols contemplate a set of documents required for the execution of the evaluation methods. • Consolidate the information in the "Experiment Design document". * It is recommended, if possible, that aspects, such as scenarios and tasks, are universally defined to use in multiple evaluation methods.
What is obtained?	• ③ Experiment Design Document.

Table P. Evaluators Selection Specification

S1.3 Evaluators Selection Search and selection of evaluators.	
What do I need to get started?	• ① System, product, or service information.
What to do?	• Analyze system, product, or service information. • Select experts in UX/Usability, experts in the ASD domain and/or experts with knowledge in both areas (UX/Usability and in the ASD domain). • Select a leader with knowledge in both areas (UX/Usability and in the ASD domain) or a UX/Usability expert. • Collect information from expert evaluators. • Consolidate the list of expert evaluators.
What is obtained?	• ④ List of evaluators.

Table Q. Participants Selection Specification

S1.4 Participants Selection Search and selection of participants with ASD and their tutors.	
What do I need to get started?	• ① System, product, or service information.
What to do?	• Define target users. • Search for participants with ASD. ○ Have the permission of the guardians if necessary. • Search and list tutors, if needed.

	○ It is recommended that they are people close to the participants with ASD. • Collect the information obtained from the participants. • Consolidate the list of participants.
What is obtained?	• ⑤ List of participants.

Table R. Execution Stage Specification

S2: Execution Stage Execution of selected evaluation methods.	
What do I need to get started?	• ② List of methods to execute. • ③ Experiment Design Document. • ④ List of evaluators. • ⑤ List of participants.
What to do?	• Collect information obtained in the planning stage. • Evaluators training. • Execute the preliminary evaluation. • Execute the inspection methods. • Execute user tests. • Document the results obtained in each of the evaluations.
What is obtained?	• ⑥ Results of the execution of the preliminary evaluation. • ⑦ Results of the execution of the inspection method(s). • ⑧ Results of the execution of the user test(s).

Table S. Property Checklist Specification

Property Checklist	
Input	• ③ Experiment Design Document: ○ Goals. ○ Protocol. ○ Scenarios (Optional). ○ Tasks (Optional). ○ Expected results. • Checklist tool/s to use. • ④ List of evaluators.
Execution Step	• For further details and specification of the method refer to study [151]. • We recommend that the evaluators must indicate compliance with each of the items on the checklist provided and may also add comments for each item or in general.
Output	• Percentage of system, product, or service satisfaction for people with ASD *. ○ Percentage of satisfaction per category ** = (average score per category/maximum score to be achieved) * 100. ○ Total satisfaction percentage = average percentage of satisfaction of all categories. • System Perception Questionnaire. ○ Comments and/or recommendations of the evaluators. • Preliminary questionnaire (Demographic).

	* The percentage of satisfaction of the system considers that each item of the property checklist will be evaluated on a Likert scale, as proposed in our property checklist adaptation [176]. ** It is proposed to categorize the items of the property checklist [176], to obtain an overview of the successes and failures in the design of the evaluated system, product or services.

Table T. Group-Based Expert Walkthrough Specification

Group-Based Expert Walkthrough	

Input	• ③ Experiment Design Document:
	  ○ Goals.
	  ○ Protocol.
	  ○ Scenarios.
	  ○ Tasks.
	  ○ Expected results.
	• ④ List of evaluators.

Execution Step	• For further details and specification of the method refer to the study [152]. • The author of the group-based expert walkthrough method only proposes the assignment of the severity scale [152]. For the purposes of the methodology, we recommend using the frequency and criticality scales.

Output	• List of potential problems.
	  ○ Details about severity, frequency and criticality can be found in Table N.
	• List of tasks performed.
	  ○ Document completed by the evaluators.
	• System Perception Questionnaire.
	  ○ Comments and/or recommendations of the evaluators.
	• Preliminary questionnaire (Demographics).

Table U. Perspective-Based Inspection Specification

Perspective-Based Inspection	

Input	• ③ Experiment Design Document:
	  ○ Goals.
	  ○ Protocol.
	  ○ Scenarios.
	  ○ Tasks.
	  ○ Expected results.
	• ④ List of evaluators.

Execution Step	• For further details and specification of the method refer to the study [153]. • The authors of the perspective-based inspection method only propose the assignment of the severity scale. For the purposes of the methodology, we recommend using the frequency and criticality scales.

Output	• List of potential problems.
	  ○ There will be a list of problems for each perspective.
	  ○ Details about severity, frequency and criticality can be found in Table N
	  ○ The values of severity, frequency and critique are agreed by all the evaluators.
	• List of tasks performed.
	  ○ Document completed by each evaluator.
	• System Perception Questionnaire.

	○ Comments and/or recommendations of the evaluators. • Preliminary questionnaire (Demographics).

Table V. Heuristic Evaluation Specification

Heuristic Evaluation	
Input	• ③ Experiment Design Document: ○ Goals. ○ Protocol. ○ Scenarios (Optional). ○ Tasks (Optional). ○ Expected results. • ④ List of evaluators: • Set of selected heuristics.
Execution Step	• For further details and specification of the method, refer to study [7]. For the purposes of the methodology, we recommend using the frequency and criticality scales. • This stage can be a free exploration of the system, product or service or it can be guided by a set of tasks, depending on what is indicated in the execution plan.
Output	• List of potential problems. ○ Details about severity, frequency and criticality can be found in Table N. • List of tasks performed *. ○ Document completed by each evaluator. • System Perception Questionnaire. ○ Comments and/or recommendations of the evaluators. • Preliminary questionnaire (Demographics). * Depending on the execution plan, it may or may not be necessary.

Table W. Field Observations Specification

Field Observations	
Input	• ③ Experiment Design Document: ○ Goals. ○ Protocol. ○ Expected results. • ⑤ List of participants.
Execution Step	• For further details and specification of the method refer to the study [151]. • Consider the general and specific recommendations of the evaluation method presented in section S2.3 User Tests.
Output	• System Perception Questionnaire. ○ Comments and/or recommendations from the participants and/or tutors. Tutors are only part of the experiment if needed. • Audiovisual and written records. • List of potential problems. ○ Potential problems found by the evaluation observers. • Observers log. ○ List of observations about the behavior and involvement of users during interaction with the system. • Confidentiality agreement.

Table X. Controlled Observations Specification

Controlled Observations	

Input	• ③ Experiment Design Document:
	  ○ Goals.
	  ○ Protocol.
	  ○ Scenarios.
	  ○ Tasks.
	  ○ Expected results.
	• ⑤ List of participants.

Execution Step	• For further details and specification of the method refer to the study [151]. • Consider the general and specific recommendations of the evaluation method presented in section S2.3 User Tests.

Output	• System Perception Questionnaire.
	  ○ Comments and/or recommendations from the participants and/or tutors. Tutors are only part of the experiment if needed.
	• Audiovisual and written records.
	• List of potential problems.
	  ○ Potential problems found by the evaluation observers.
	• Task list.
	  ○ Completed by the participants.
	• Observers log.
	  ○ List of observations about the behavior and involvement of users during interaction with the system.
	  ○ Performance measures of the tasks performed (time and number of tasks performed).
	• Confidentiality agreement.
	• Preliminary questionnaire (Demographics).

Table Y. Results Analysis Stage Specification

S3: Results Analysis Stage Analysis and report of the results found.	
What do I need to get started?	• ⑥ Results of the execution of the preliminary evaluation. • ⑦ Results of the execution of the inspection method(s). • ⑧ Results of the execution of the user test(s).
What to do?	• Group the results obtained from the evaluations carried out. • Quantitative analysis. • Qualitative analysis. • Create the UX evaluation report.
What is obtained?	• ⑨ Results of quantitative analysis. • ⑩ Results of qualitative analysis. • ⑪ UX evaluation report.

APPENDIX E

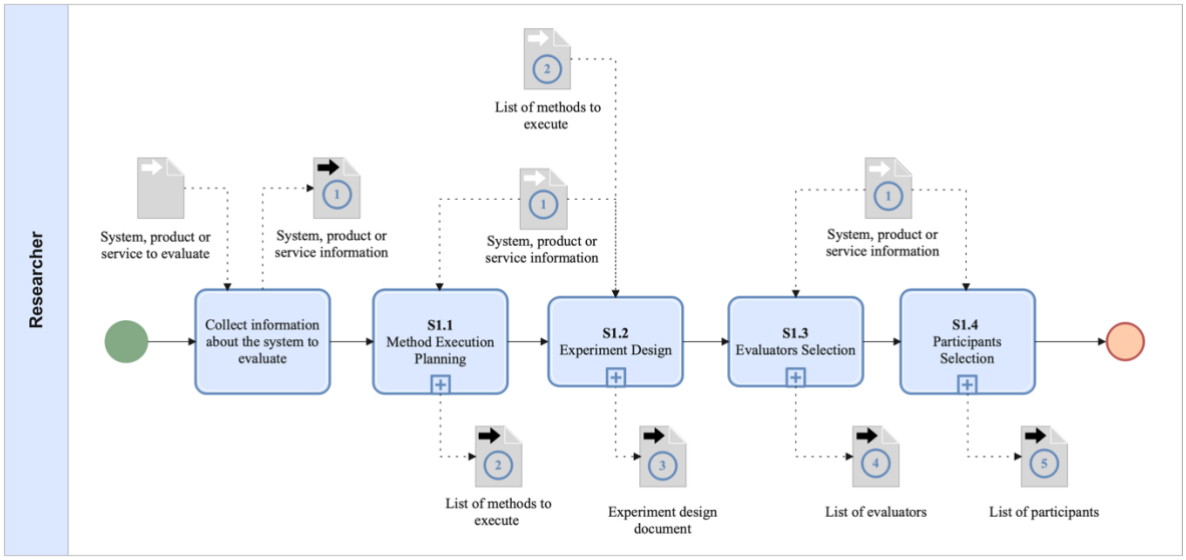


Figure A. S1 Planning Stage Diagram

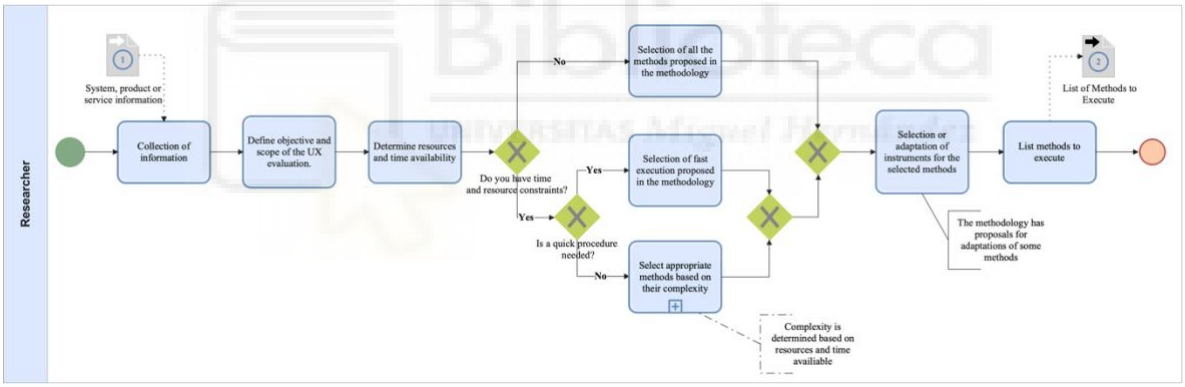


Figure B. S1.1 Method Execution Planning Diagram

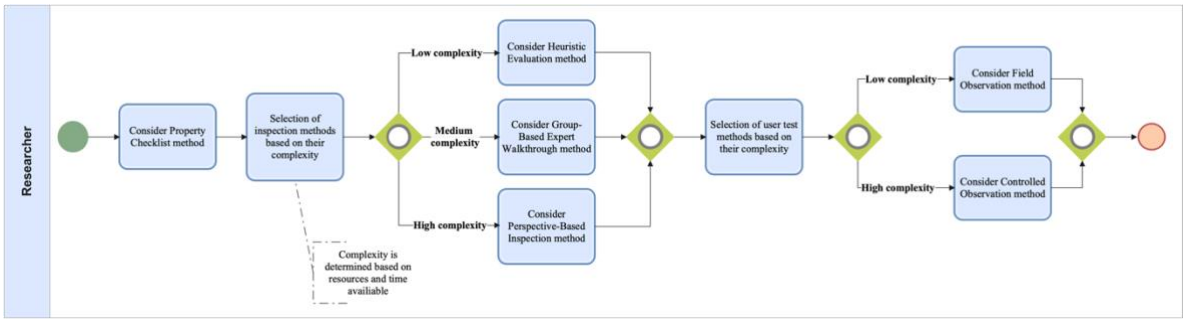


Figure C. S1.1 Method Execution Planning Subprocess Diagram

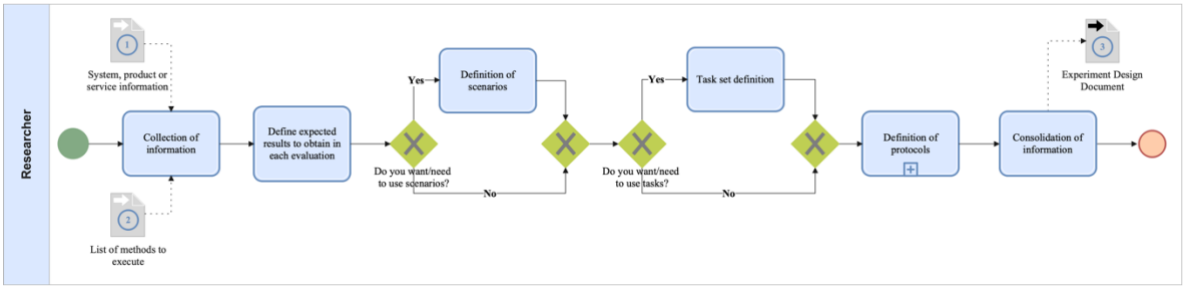


Figure D. S1.2 Experiment Design Diagram

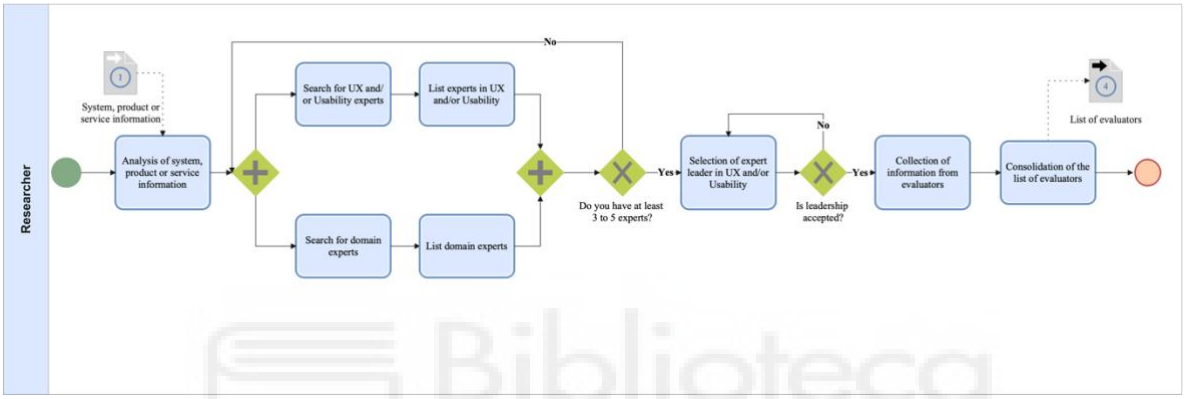


Figure E. S1.3 Evaluators Selection Diagram

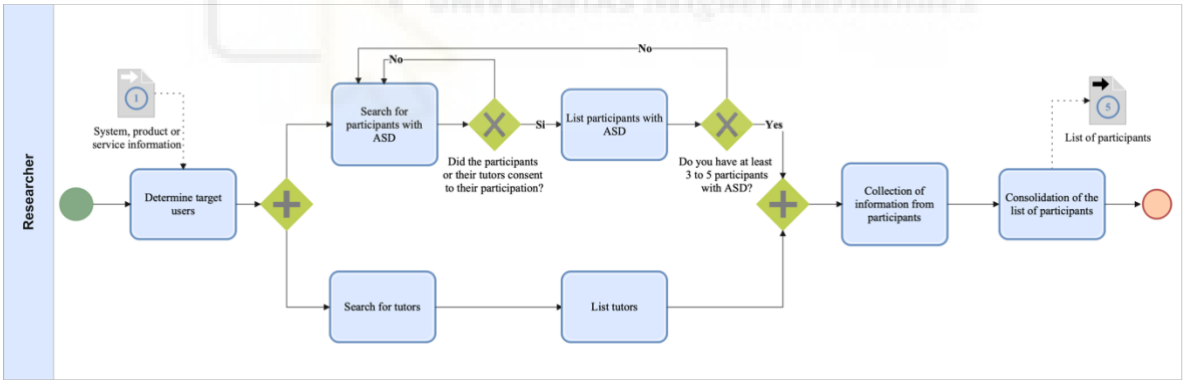


Figure F. S1.4 Participants Selection Diagram

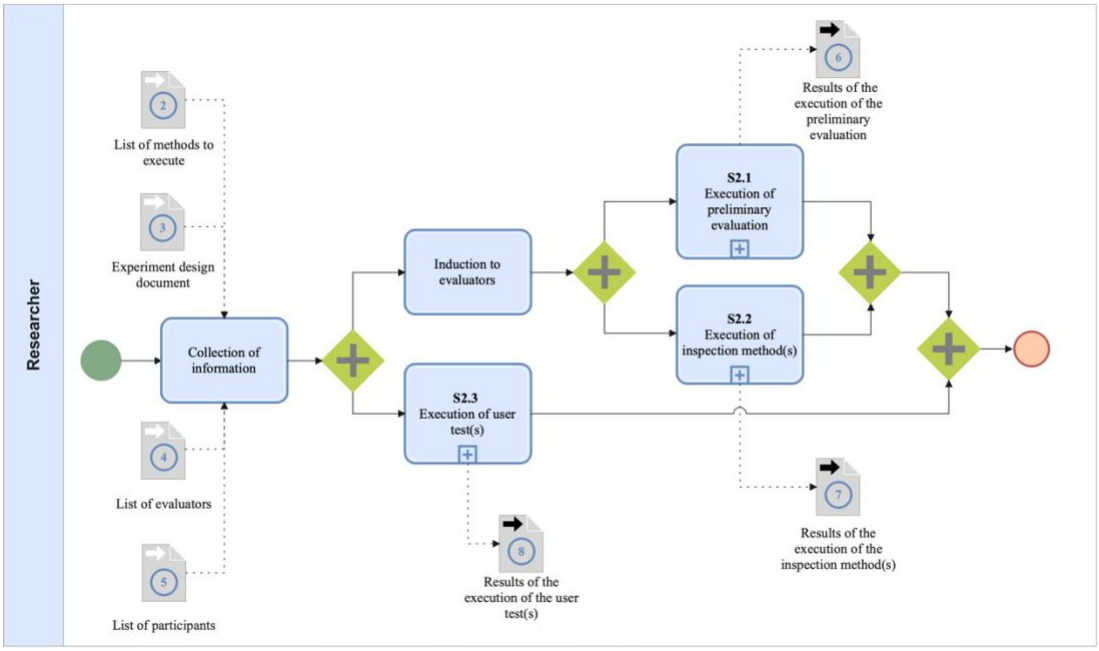


Figure G. S2 Execution Stage Diagram

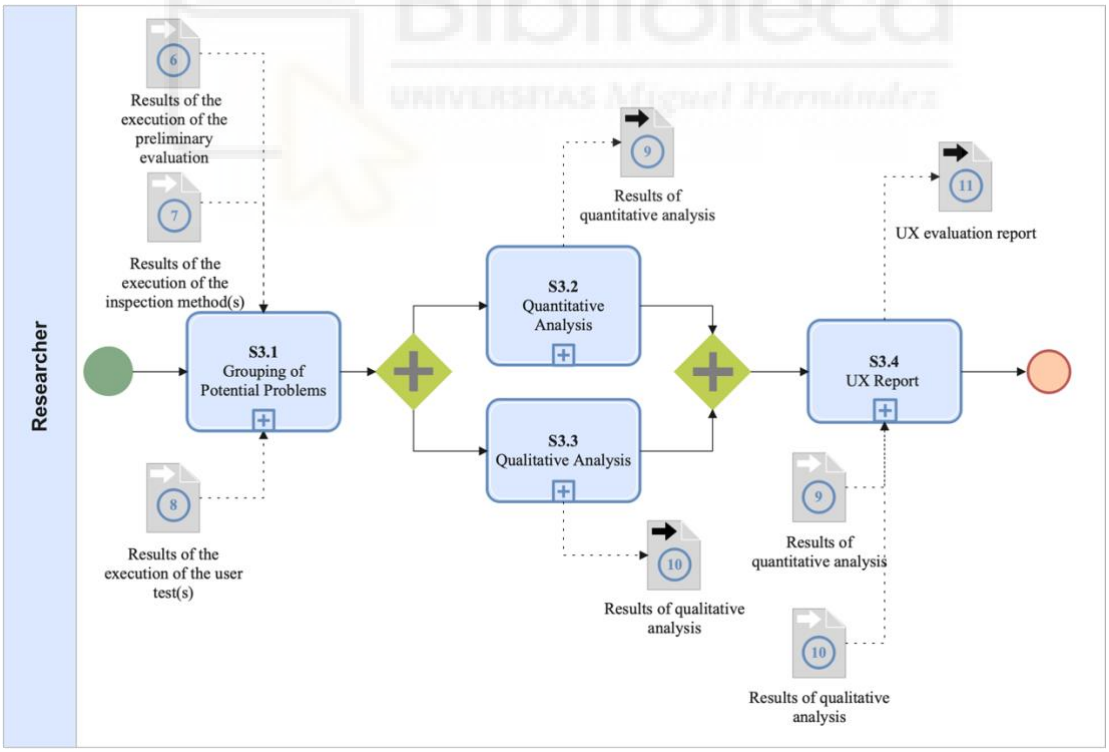


Figure H. S3 Results Analysis Stage Diagram

APPENDIX F

Find our property checklist proposal below.

1. *Engaging:* The system commits the user to interact with it.
   1.1. The system delivers constant feedback to the user in a clear and concise manner. This must be not only through text but also through visual elements or audio.
   1.2. The system provides rewards to the user for positive actions or good performance.
   1.3. The system has a history of the actions performed by the user.
2. *Predictable:* The system has a predictable environment, generating an environment of trust among users.
   2.1. The system doesn't have sudden and unexpected actions.
   2.2. The content of the system is predictable and consistent.
   2.3. The system allows repeating actions, tasks or activities.
3. *Structured:* The system is structured.
   3.1. The system's navigational setup, aesthetics, and content are structured and consistent.
   3.2. Navigation in the system is simple and logical.
4. *Interactive:* The system generates interactions considering the characteristics, affinities and needs of the users, as well as their difficulties in social interactions.
   4.1. Each task has a clear and explicit objective.
   4.2. Instructions on the system are clear, simple, brief and context appropriate.
   4.3. The system provides elements to minimize the memory load of the user (for example: grouping and delivering the necessary and concise information to the user).
5. *Generalizable:* The system is familiar enough and similar to real life to facilitate generalizing skills.
   5.1. Activities, tasks or information in the system are based on previously learned activities, tasks or information.
   5.2. The interaction with the system is familiar and similar to the real life of the users.
6. *Customizable:* The system can be customized considering the needs, abilities and preferences of people with ASD.
   6.1. The system allows users and tutors to customize aspects quickly, easily and effortlessly. (e.g., disable sounds, configure the level and intensity of the sounds, modify the color palette, font type, size, layout and activity times).
   6.2. The system has a predefined basic configuration that considers the characteristics, affinities and needs of users with ASD.
7. Sense-aware: The system considers the senses of users with ASD.
   7.1. The system provides information to the user through multimedia, texts, among others.
   7.2. The visual and sound elements are clear, meaningful, functional, non-disruptive and legible.
   7.3. The actions and states of the system are clear and simple.
   7.4. The system interface is clear, simple and minimalist.

7.5. Texts have clear messages, readable font size and type, and are free of rhetorical figures.

8. Attention Retaining: The system retains users' attention and manages time appropriately.
   8.1. The system responds to user actions in real time and without delays.
   8.2. The system provides dynamic stimuli such as animations and/or controlled music to attract users' attention.
   8.3. The system views do not provide distracting elements.
9. Frustration Free: The system tries to avoid the frustration of its users during their interaction.
   9.1. The system allows you to confirm, cancel or repair unwanted actions.
   9.2. The system displays error messages in plain language, accurately indicates the problem and constructively suggests how to avoid such errors.
   9.3. The documentation and help provided by the system is provided in a visual, textual, concrete, not extensive and structured way.

APPENDIX G

The heuristics for people with ASD proposed by Castro et.al are presented below.

Table Z. Heuristics for People with ASD

ID	Heuristic Name	Heuristic Definition
ASDUX1	System status visibility	The system must always keep users informed about the processes and status changes that occur, in order to be able to give the user the necessary elements to know what will happen and thus lower uncertainty.
ASDUX2	Match between the system and the real world	The system must speak the language of the users with familiar concepts, which must be structured, instead of system-oriented terms so that the user can more easily interpret and generalize.
ASDUX3	Consistency and standards	Allow users to customize frequent actions as needed by either shortcuts or toolbars, so that actions are not frustrating because they are unnecessary.
ASDUX4	Recognition instead of remembering.	Minimize the user's memory load by making objects, actions and options of the system, product or service visible, so that they do not have to be searched for, thus helping to retain attention on the desired task. The user should not have to remember information from one part of the interface to another. The instructions for use of the system must be visible or easily retrievable whenever appropriate.
ASDUX5	Aesthetic and minimalist design.	The user interface design should not contain information that is irrelevant or rarely needed, as it can distract the user's attention, so that only important or essential information is displayed, making it easier for the user to perform a task.
ASDUX6	User control and freedom.	Users can make errors in the system, so there must be a clearly marked "emergency exit" to get out of unwanted states, which allows easy recovery from errors avoiding frustration, increasing confidence and making system operation predictable. system to the user. The system should allow users to move from one section to another and provide the facility to perform activities repetitively
ASDUX7	Error prevention.	The system provides confirmation options which contain information about what you want to do before the user commits to an action to avoid the frustration of making a mistake. If users select wrong options, the system should provide alternative options for them to choose from.
ASDUX8	Flexibility and efficiency of use.	Allow users to customize frequent actions as needed by either shortcuts or toolbars, so that actions are not frustrating because they are unnecessary.
ASDUX9	Help users recognize, diagnose, and recover from errors.	Error messages must be expressed in a language understandable to the user. The system should provide multimedia demonstrations to give hints to the user when an error occurs, in order to avoid frustration from not easily understanding why it occurs or how to overcome it.

ASDUX10	Help and documentation.	Documentation and any help information should be easy to find, focused on the user's task, providing a multimedia demonstration of the tasks to be performed at an easily viewable size.
ASDUX11	Customization of interface elements.	The system must allow the customization of the interface elements according to the needs, abilities and preferences of each user. Interface elements should be large enough that users can read and interact with them without difficulty due to their size. That should also allow them to change various settings for system background, font, color, screen size, and others.
ASDUX12	Unexpected changes in the system interface.	Changes to the interface must be done step by step. Users cannot cope with sudden or drastic changes being made.
ASDUX13	System response capacity.	The actions carried out by the user should not have latency since they can lose attention from the task they were doing; this can cause the user to forget and get frustrated easily. The system responds to user actions without latency, allowing you to focus on the task at hand without getting frustrated.
ASDUX14	Track user activities and monitor performance.	The system must keep a history of all the activities carried out by the user, time spent, answers provided, results and others, in case you have not paid the necessary attention, the system must allow the user to return to past activities.
ASDUX15	Use of multimodalities for communication.	Users must have the option of using different devices to interact with the system. In addition, the system must offer several options to communicate, be it text, audio, images, video, etc.
ASDUX16	Structured interface.	The system must maintain a design which the user can know as he interacts, where to find the options that it offers because its structure is logical, simple and consistent. Keeping at all times, as needed, everything in its place.

APPENDIX H

Tasks to Perform

PlanTEA is a mobile application that allows planning and anticipating the attendance of children or adults with Autism Spectrum Disorder (ASD) at medical consultations, as well as facilitating communication with specialists through a communication notebook.

When using the PlanTEA app, consider the context:

On June 9 at 4:00 p.m. you have an appointment to get a flu shot at your health center, which **IS NOT SCHEDULED** in the PlanTEA application.
To plan your appointment at the doctor's office, consider that you should at least: leave home, go to the doctor's office and vaccination room, wait your turn, contemplate an activity while you wait, have the nurse tell you that it is your turn, disinfect, vaccinate and put a patch, wait after vaccination and finally return home.

Therefore, you will need to access the PlanTEA application through the **scheduler** profile, using the tablet that has been issued to you. We ask you to perform each of the following tasks, and if possible and comfortable, comment aloud throughout the experiment.

ENTER THE PLANTEA APP (all tasks can be performed without having to exit the application). And perform the following tasks:

1. **First Task.**
   You must plan your appointment to get a flu shot in the PlanTEA application considering the context mentioned above, through the **SCHEDULER** profile. Consider that the password is **123abcd**.
   - Have you been able to find the day you should schedule your appointment?: _____
   - What type of consultation is the one you have indicated in the application?: _____
   - Have you been able to correctly plan your appointment in the application for the day and time indicated? _____

2. **Second Task.**
Enter the **USER** profile. The app has a calming object in case you feel overwhelmed. Answer:
   - Can you find the calming object? _____
   - What is this calming object?: _____

APPENDIX I

To test the proposed methodology in section 12 [12], the methodology was applied to the mobile application PlanTEA and the website www.expedia.com. The details of each case study conducted are presented below.

1 PlanTEA Case Study

To evaluate the UX of the PlanTEA application, the following evaluation methods were applied: property checklist [151], heuristic evaluation [7] and field observation [151]. In the application of these evaluation methods, we had the support of 5 experts with knowledge in UX, ASD and in both areas for each inspection method, and the participation of 7 adults diagnosed with ASD level 1 from AUTRADE [183] for the field observation.

The following section describes what was done and the results obtained in each of the evaluation methods applied to evaluate the PlanTEA application user experience.

2 Inspections

To evaluate the user experience in the PlanTEA application, two inspection methods were performed: property checklist and heuristic evaluation. For each evaluation method, we requested the help from a total of 10 evaluators, 5 for each inspection method.

The evaluators were sent by e-mail the instructions for the evaluation to be carried out and an Excel file that included instructions, preliminary and perception questionnaires and formatted sheets to complete the required information depending on the inspection method to be carried out. The structure of the Excel file is presented below:

1. Presentation of the evaluation to be carried out.
2. Preliminary questionnaire, which contains a total of 10 questions focused on the knowledge and previous experiences of the evaluators.
3. Formatted spreadsheets to facilitate inspection.
4. Perception Questionnaire, which presents 17 questions focused on knowing the perception of the evaluator after interacting with the PlanTEA mobile application.

For the evaluation of the property checklist, they were provided with the property checklist specification, which consists of 9 categories and 26 items. The evaluators, who then interacted with the PlanTEA application, had to evaluate the compliance of each of the items presented in the property checklist by means of a scale of 1-5 (1: Not complied with at all - 5: Fully complied with), and optionally provide comments/observations on each item.

For the heuristic evaluation, the following was provided: (1) list and detail of the selected heuristics and (2) spreadsheet to be completed by the evaluator with each potential problem found after interacting with the PlanTEA application. For each potential problem, the evaluators had to provide a definition, an explanation, the path taken to find the problem, identify an image with the problem, and assign the unmet heuristic according to their criteria.

The results obtained in the questionnaires and inspection methods carried out are presented below.

2.1 Preliminary Questionnaire

The experts' profiles include PhD students, computer scientists with UX/Usability expertise, and domain specific experts, such as psychologists and counselors with hands-on experience working with people with ASD. Some of these experts have experience in both UX/Usability and ASD, and some have ASD themselves. As a result, we have obtained the following information:

- A total of 9 experts (90%) previously knew the concepts of UX/Usability.
- All experts previously knew the ASD concept.
- A total of 3 experts (30%) have previously used applications and/or systems designed for people with ASD. The 3 experts indicated that their experience with said applications and/or systems was good and/or ok.

2.2 Property Checklist

To evaluate the PlanTEA mobile application, we adapted our proposed property checklist to evaluate the UX for people with ASD [176]. This adaptation consists of a compact version [176] that includes 9 categories with a total of 26 items. The adaptation of the property checklist used is presented in appendix F.

A total of 5 expert evaluators with knowledge in UX, ASD and in both areas evaluated the PlanTEA application using the adapted property checklist (see appendix F).

Considering the answers obtained by the evaluators and the calculation considerations raised in our methodology [12], we can state that the percentage of satisfaction of the PlanTEA application is 68.5%.

The percentages of satisfaction obtained by each category, detailed in our property checklist proposal [176], are presented in Table AA.

Table AA. PlanTEA Satisfaction Percentage

Category name	Satisfaction percentage
Engaging	61.7%
Predictable	76.7%
Structured	62.0%
Interactive	72.0%
Generalizable	70.0%
Customizable	64.0%
Sense-aware	72.4%
Attention Retaining	75.0%
Frustration Free	62.7%
Average Satisfaction	68.5%

Graphing the information obtained in Table AA, as proposed in the methodology [12], Figure I is obtained as a result.

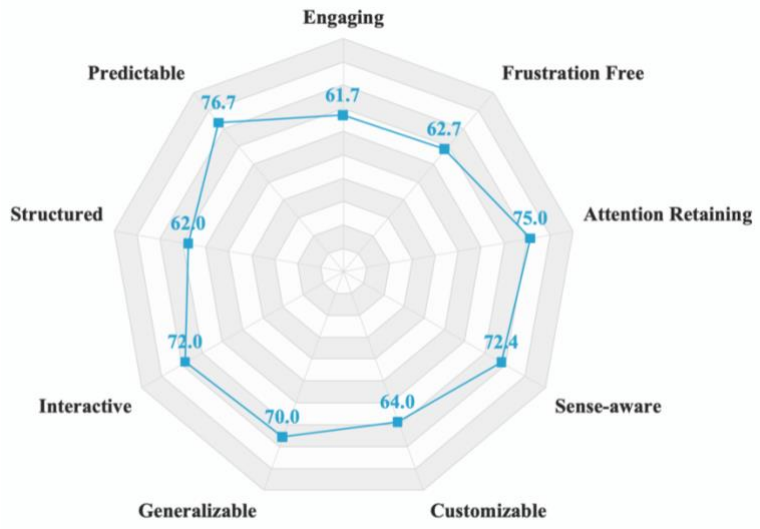


Figure I. PlanTEA satisfaction percentage per category

The highest percentages of satisfaction are presented in the predictable and attention retaining categories, with 76.7% and 75% respectively.

The evaluators commented on the predictable category: (1) "the application behaves coherently with the actions performed", (2) "arbitrary behavior does not occur when faced with actions performed by the user" and (3) "the application allows repetitive actions, but there is room for improvement, such as being able to copy and paste events or groups of elements". However, it is also mentioned that: (1) "the animations of some pictograms are unexpected" and (2) "the way you interact with the pictograms is not predictable".

Regarding the attention-retaining category, the evaluators noted that: (1) "the application generally works correctly, although some functions have a small delay when interacting with them", (2) "I did not see any distracting element during my interaction with the application". It's also mentioned that "sometimes the app has an excess of buttons and information".

On the other hand, the lowest percentages of satisfaction are shown in the categories of engaging, structured and frustration-free, with 61.7%, 62% and 62.7% respectively.

The evaluators commented on the engaging category that: (1) "the application gives little feedback about the actions performed, or in some cases it is not very visible" and (2) "there is no history of actions that have been carried out". However, it is also mentioned that "the application delivers visual stimuli when an action is performed correctly".

Regarding the structured category, evaluators noted that: (1) “there is inconsistency in how the application elements work” and (2) “the event creation process does not have a clear logic.” However, it also mentions that "browsing is generally consistent".

Evaluators commented on the frustration-free category that: (1) "there are no error recovery options", (2) "error messages are small and hard to see" and (3) "the documentation is extensive and is not structured in a simple way". They also mention that "the documentation provided is helpful".

The 9 categories presented were qualified by the evaluators with satisfaction percentages higher than 61%. The predictability and ability of the application to capture the user's attention is positively highlighted. On the other hand, the need to provide clear and

timely feedback, maintain consistency in the current elements of the application and provide better error handling is highlighted and needs to be addressed to improve the user experience when using the application.

2.3 Heuristic Evaluation

A set of 16 heuristics was used to evaluate the UX of the PlanTEA application. The set used was created by Castro et. al, which was developed to evaluate the user experience of systems used by people with ASD. For more details on the heuristics used, see appendix G.

A total of 5 expert evaluators with knowledge in UX, ASD and in both areas evaluated the PlanTEA application using the set of selected heuristics.

To perform the heuristic evaluation, two phases were performed, namely:

1. The evaluators, after interacting with the PlanTEA application, describe the potential problems found. The evaluators were asked to identify at least 10 potential problems. For each potential problem found, the evaluator provides a definition, comments and/or explanations about the identified problem, the path taken to find the potential problem, unmet heuristics, and an image example.
2. All potential problems identified by all evaluators are consolidated. If duplicate potential problems are found, their definitions and explanations are consolidated to generate a single potential problem. Once all the potential problems identified by the evaluators are compiled and consolidated into a single list, the evaluators are asked to assign a frequency and severity for each potential problem (for more details on the frequency and severity scales see Table N in appendix D).

2.3.1 Potential Problems Found

Each evaluator identified between 10 and 21 potential problems, which were consolidated to eliminate potential duplicate problems. As a final result, a total of 43 potential problems in the PlanTEA application were identified, as can be seen in Table BB.

Table BB. Potential problems found on PlanTEA

ID	Problem Definition	Comments and Explanation	Path to get to the problem	Unfulfilled Heuristic (Castro et.al)
P1	There is no differentiation between users and objects	The iconography and way of entering the info for the planner/user and "reassuring object" users is similar and may suggest that the "reassuring object" may be another user/actor of the system.	Preferences	ASDUX2
P2	Options use iconography and do not include text that represents	Most of the icons used in the system do not have a text that shows what action they perform. This is often confusing.	Preferences	ASDUX15
P3	It is not allowed to "schedule" without	The "schedule" button is disabled until a time is selected, not allowing the default	Planner	ASDUX8

	selecting the default time	time to be selected. This also applies to select the "consultation type".		
P4	The "schedule" button does not schedule immediately	When you press plan, you must then press "new planning" to start the process. The middle step seems unnecessary and misleads from expectations.	Planner	ASDUX13
P5	Schedule date and time are not displayed throughout the process	When starting a schedule, the time and date selected on the previous screen are not displayed.	Planner	ASDUX4
P6	Difficult pictogram movement in planning	When selecting schedule cards, they must be dragged "hard" to be able to move them.	Planner	ASDUX13
P7	Confusing pictogram categories	It is not clear which pictograms are "categories" that include more pictograms inside, since they share a similar design with the pictograms that are selectable.	Planner	ASDUX3
P8	Difficulty removing a pictogram	The action to "remove" a glyph from the timeline is not intuitive. To remove a card, you must drag it up, which is the same action used to move from the bottom selection to the timeline.	Planner	ASDUX3
P9	Step repetition to select pictograms from the "action" category	The pictograms in the "action" category are probably the most frequently used in the system, so it is inefficient to go back through the menus to select them.	Planner	ASDUX8
P10	Frame consistency for different types of pictograms	The Pictograms have different frames to represent the "entertainment" and "reward" categories, while the rest have no frame at all. This can be distracting and is inconsistent.	Planner	ASDUX5
P11	Hard to see error messages and confirmation of actions	The error message when trying to save without entering a title when creating a schedule is small and inconspicuous, which may cause the issue to be ignored and not easily resolved.	Planner	ASDUX7
P12	Activity and event icons are unclear	Activity icons aren't clear, and it's easy to accidentally create duplicate events by not forcing the title change.	Planner	ASDUX9
P13	Non-modifiable consultation type and time	The events cannot be changed of day and/or type of planning.	Planner	ASDUX8
P14	Elimination of progress when changing day	Changing the day after creating an event, without pressing save on the screen, causes	Planner	ASDUX9

		the progress to be deleted. There is no warning about it. When you select the day again and press schedule, the event appears again.		
P15	Confusing and inconsistent event visibility	The visibility icon of an event is not clear regarding the status of the event. In addition, only one event is allowed to be visible, despite being on different days.	Planner	ASDUX4
P16	Events visible out of date	Events visible in the user's profile even though said event was scheduled for previous days. Example: The user can interact with the event scheduled for October 15 and at the time of review this is November 2.	Planner	ASDUX3
P17	Difficulty and inconsistency in saving an event on a specific day	To be able to save an event created in a day, it must be selected by holding down the card and then pressing save. This is very unintuitive when it comes to assigning the event to the day it was created.	Planner	ASDUX6
P18	Scroll not evident in communication notebook box	The box that contains the pictograms in the user's communication notebook does not seem to be scrollable (move), although it is. It is possible not to see that there are more pictograms below those shown by default.	Communications notebook	ASDUX1
P19	Unclear and contradictory pictogram intensity	The pictograms in the communication notebook show a bar indicating "intensity", it is not immediately clear what it represents. In addition, the pictograms are presented with a negative connotation, so it is possible that selecting the intensity can cause a double negation of the user's intention.	Communications notebook	ASDUX2
P20	Difficulty closing pictograms	The pictograms displayed on the plan are difficult to close in the app, as there is an area around the image where the image cannot be closed. There is also no close icon or button.	Planner	ASDUX1
P21	Inconsistency and animations in entertainment pictograms and rewards	Pictograms for entertainment and rewards have different frames and play animations. These animations only apply to this type of pictograms and can be "surprising".	Planner	ASDUX12
P22	Unintuitive user manual	The user manual is difficult to navigate and is not consistent in its section numbering. Section 2 includes subsections shown with dashes; however the others include subsections with subpoints like 4.	User Manual	ASDUX10
P23	Application responsiveness	The application is not adapted to all types of tablet screens. This produces that some texts	General	ASDUX7

	on different devices	or sections are not displayed correctly or are difficult to use.		
P24	Too much information	By pressing the "user manual" button, the system always offers the same manual with complete information and must be focused on the user's task.	General	ASDUX10
P25	No customization of interface elements	The system does not allow customizing the interface elements so that they are adapted to the user's needs.	General	ASDUX11
P26	Lack of audio help in the user manual	The application lacks audio aids to read/explain sections of the user manual.	User Manual	ASDUX15
P27	Actions carried out with unrepresentative icon	Marking actions performed in gray may not be so noticeable for the user to perceive this task as done, so there should be another way to represent when an action is complete.	Planner	ASDUX11
P28	Confirm a schedule	When pressing the "Save" button, the system must ask to confirm this option to avoid errors. I understand that this section of the system is not intended for the user with ASD, but I think that the user can participate in the entire process (creation and monitoring of events).	Planner	ASDUX7
P29	Make actions easier	It is possible that being a long planning, this is frustrating for the user having to drag all the actions/pictogram. The system should allow adding tasks by pressing the action/pictogram without dragging it.	Planner	ASDUX8
P30	Unexpected closing of the app	When you click on the arrow (upper left) of the application, it closes unexpectedly.	Preferences	ASDUX7
P31	Unnecessary information	Information appears as blocked, instead of appearing only when the "appointment notifications" option is selected.	Preferences	ASDUX5
P32	User manual slow to load	Clicking on the user manual does not load immediately. A loading screen should be provided indicating that it was pressed and that the button is blocked so that it cannot be clicked further.	Preferences	ASDUX1
P33	Lack of welcome tour	If I hadn't been curious about the documentation, I wouldn't have found out that I was making settings for the first-time use of the application, a tour is needed showing each functionality and what each thing means.	Preferences	ASDUX10

P34	Lack of linguistic connectors	Message with missing linguistic connectors. What can cause that at first instance the "planner information" section is not understood. This can be interpreted as another object or a person/profile.	Preferences	ASDUX3
P35	Password modification icon	The planner profile password change icon is unclear.	Preferences	ASDUX2
P36	Difficulty closing popup screen	Inside the red box there is a layer that does not allow you to exit the page, if you press outside the red box the pictogram closes but otherwise it does not answer or answers with a delay.	Communications notebook	ASDUX13
P37	Delete an event	When you delete an event, it doesn't immediately disappear from the calendar.	Planner	ASDUX2
P38	Image of profiles and calming object	The application only allows uploading an image from the device's gallery. Cannot access the camera to take a photo at the moment.	Preferences	ASDUX2
P39	Obligation of actions of different types of users	Existen múltiples elementos y acciones de la aplicación que son de carácter obligatorio, sin embargo estos no son necesarios para algunos perfiles de usuarios que utilizaran la aplicación (por ejemplo: adultos que pueden crear sus propias planificaciones), como lo son los dos tipos de perfiles, contraseñas y el uso de un objeto tranquilizador.	Preferences	ASDUX8
P40	Non-descriptive consultation type	There are multiple elements and actions of the application that are mandatory, however these are not necessary for some user profiles that will use the application (for example: adults who can create their own schedules), as are the two types of profiles, passwords and the use of a reassuring object.	Planner	ASDUX3
P41	Confusion between the "New planning" button and the planning section.	When it says new planning, it seems that what you have to do is another plan, not that it is within the same plan.	Planner	ASDUX3
P42	User profile has no calendar	In case the planner is also the user, the application should present the same calendar shown in the planner's profile.	General	ASDUX16
P43	Intention of the communications notebook	The purpose and intention of the communications notebook is not clear, since a description of its use is missing.	Communications notebook	ASDUX10

Although several potential duplicate issues were found, the consolidated list contains a robust number of potential issues. We believe that the diversity of potential problems found,

consolidated in the Table BB, is due to the experience of the evaluators in UX/Usability evaluations and the ASD condition.

2.3.2 Unfulfilled Heuristics

Table CC summarizes the identified potential problems associated with unfulfilled heuristics.

Table CC. Unfulfilled Heuristics on PlanTEA

ID	Heuristic	Associated Potential Problem(s)	Number of related potential problems
ASDUX1	System state visibility	P18, P20, P32	3
ASDUX2	Match between the system and the real world	P1, P19, P35, P37, P38	5
ASDUX3	Consistency and standards	P7, P8, P16, P34, P40, P41	6
ASDUX4	Recognition instead of remembering.	P5, P15	2
ASDUX5	Aesthetic and minimalist design.	P10, P31	2
ASDUX6	User control and freedom.	P17	1
ASDUX7	Error prevention.	P11, P23, P28, P30	4
ASDUX8	Flexibility and efficiency of use.	P3, P9, P13, P29, P39	5
ASDUX9	Help users recognize, diagnose, and recover from errors.	P12, P14	2
ASDUX10	Help and documentation.	P22, P24, P33, P43	4
ASDUX11	Customization of interface elements.	P25, P27	2
ASDUX12	Unexpected system interface changes.	P21	1
ASDUX13	System Responsiveness.	P4, P6, P36	3
ASDUX14	Track user activities and monitor performance.		0
ASDUX15	Use of multimodalities for communication.	P2, P26	2
ASDUX16	Structured interface.	P42	1

Most of the potential problems identified were associated with the ASDUX3, ASDUX2, and ASDUX8 heuristics, with 6, 5, and 5 potential problems, respectively. We believe that this is due to the fact that the expectations of a person with ASD regarding standards, match with the real world and flexibility of use when faced with a system such as PlanTEA are influenced by the interaction with previously used technological systems, so many of these expectations are not met by the design and interaction with PlanTEA.

On the other hand, no potential problem was associated with the ASDUX14 heuristic. We believe that this lack of association with the ASDUX14 heuristic is due to the fact that PlanTEA's functionalities and goals do not include activities to be supervised, so this heuristic is not applicable to the current state of the system.

2.3.3 Frequency, Severity and Criticality Values Assigned

Table DD shows the results obtained after each evaluator assigned a frequency and severity to each potential problem, according to the scales provided. In addition, Table DD presents the criticality of each potential problem identified by the evaluator, as well as the mean and standard deviations of the severity (S), frequency (F), and criticality (C) of each potential problem found.

Table DD. Frequency, Severity and Criticality Values Assigned on PlanTEA

		Evaluator 1			Evaluator 2			Evaluator 3			Evaluator 4			Evaluator 5			Average			Standard Deviation		
ID	**Problem Definition**	**S**	**F**	**C**	**S**	**F**	**C**	**S**	**F**	**C**	**S**	**F**	**C**	**S**	**F**	**C**	**S**	**F**	**C**	**S**	**F**	**C**
P1	There is no differentiation between users and objects	2	1	3	2	2	4	3	2	5	4	4	8	2	3	5	2.60	2.40	5.00	0.80	1.02	1.67
P2	Options use iconography and do not include text that represents	3	4	7	3	4	7	3	4	7	4	4	8	3	4	7	3.25	4.00	7.25	0.39	0.00	0.39
P3	It is not allowed to "schedule" without selecting the default time	2	2	4	1	3	4	3	1	4	4	4	8	4	4	8	2.80	2.80	5.60	1.17	1.17	1.96
P4	The "schedule" button does not schedule immediately	4	3	7	1	3	4	2	1	3	4	4	8	4	4	8	3.00	3.00	6.00	1.26	1.10	2.10
P5	Schedule date and time are not displayed throughout the process	2	2	4	2	3	5	2	2	4	3	4	7	2	4	6	2.20	3.00	5.20	0.40	0.89	1.17

P6	Difficult pictogram movement in planning	4	3	7	4	3	7	3	3	6	4	3	7	4	4	8	3.80	3.20	7.00	0.40	0.40	0.63
P7	Confusing pictogram categories	2	3	5	4	4	8	3	2	5	4	4	8	4	4	8	3.40	3.40	6.80	0.80	0.80	1.47
P8	Difficulty removing a pictogram	3	3	6	4	3	7	3	2	5	4	3	7	4	3	7	3.60	2.80	6.40	0.49	0.40	0.80
P9	Step repetition to select pictograms from the "action" category	2	2	4	2	3	5	2	1	3	4	4	8	4	4	8	2.80	2.80	5.60	0.98	1.17	2.06
P10	Frame consistency for different types of pictograms	1	2	3	2	3	5	2	3	5	2	2	4	2	3	5	1.80	2.60	4.40	0.40	0.49	0.80
P11	Hard to see error messages and confirmation of actions	2	3	5	2	2	4	1	2	3	3	2	5	4	4	8	2.40	2.60	5.00	1.02	0.80	1.67
P12	Activity and event icons are unclear	2	2	4	1	2	3	2	2	4	4	2	6	2	2	4	2.20	2.00	4.20	0.98	0.00	0.98

P13	Non-modifiable consultation type and time	1	2	3	1	2	3	3	3	6	4	4	8	4	4	8	2.60	3.00	5.60	1.36	0.89	2.24
P14	Elimination of progress when changing day	4	2	6	4	3	7	3	3	6	4	4	8	4	4	8	3.80	3.20	7.00	0.40	0.75	0.89
P15	Confusing and inconsistent event visibility	3	3	6	2	3	5	3	3	6	4	4	8	3	2	5	3.00	3.00	6.00	0.63	0.63	1.10
P16	Events visible out of date	3	2	5	4	3	7	4	3	7	4	4	8	4	4	8	3.80	3.20	7.00	0.40	0.75	1.10
P17	Difficulty and inconsistency in saving an event on a specific day	4	3	7	3	4	7	3	3	6	4	4	8	4	4	8	3.60	3.60	7.20	0.49	0.49	0.75
P18	Scroll not evident in communication notebook box	2	2	4	2	4	6	3	3	6	4	4	8	4	4	8	3.00	3.40	6.40	0.89	0.80	1.50
P19	Unclear and contradictory pictogram intensity	2	2	4	2	4	6	2	3	5	4	4	8	3	3	6	2.50	3.25	5.75	0.77	0.74	1.32
P20	Difficulty closing pictograms	2	2	4	2	3	5	3	2	5	4	3	7	3	3	6	2.80	2.60	5.40	0.75	0.49	1.02
P21	Inconsistency and animations in entertainment	2	2	4	1	3	4	3	1	4	3	2	5	2	2	4	2.20	2.00	4.20	0.75	0.63	0.40

	pictograms and rewards																					
P22	Unintuitive user manual	3	2	5	1	1	2	3	1	4	4	4	8	4	4	8	3.00	2.40	5.40	1.10	1.36	2.33
P23	Application responsiveness on different devices	4	3	7	3	4	7	4	2	6	2	2	4	1	1	2	2.80	2.40	5.20	1.17	1.02	1.94
P24	Too much information	3	3	6	2	4	6	3	2	5	4	4	8	4	4	8	3.20	3.40	6.60	0.75	0.80	1.20
P25	No customization of interface elements	2	3	5	2	4	6	2	2	4	4	4	8	4	4	8	2.80	3.40	6.20	0.98	0.80	1.60
P26	Lack of audio help in the user manual	2	2	4	2	4	6	3	2	5	4	4	8	4	4	8	3.00	3.20	6.20	0.89	0.98	1.60
P27	Actions carried out with unrepresentative icon	2	2	4	2	3	5	3	2	5	4	4	8	2	2	4	2.60	2.60	5.20	0.80	0.80	1.47
P28	Confirm a schedule	3	2	5	3	4	7	2	2	4	4	4	8	4	4	8	3.20	3.20	6.40	0.75	0.98	1.62
P29	Make actions easier	2	2	4	3	4	7	2	2	4	4	4	8	4	4	8	3.00	3.20	6.20	0.89	0.98	1.83
P30	Unexpected closing of the app	4	1	5	2	1	3	3	3	6	4	4	8	4	4	8	3.40	2.60	6.00	0.80	1.36	1.90
P31	Unnecessary information	2	2	4	2	2	4	2	2	4	4	3	7	3	3	6	2.60	2.40	5.00	0.80	0.49	1.26

P32	User manual slow to load	2	2	4	1	1	2	2	2	4	2	2	4	4	4	8	2.20	2.20	4.40	0.98	0.98	1.96
P33	Lack of welcome tour	3	1	4	0	1	1	4	1	5	4	4	8	4	4	8	3.00	2.20	5.20	1.55	1.47	2.64
P34	Lack of linguistic connectors	1	3	4	1	1	2	3	3	6	4	4	8	4	4	8	2.60	3.00	5.60	1.36	1.10	2.33
P35	Password modification icon	1	2	3	1	1	2	2	1	3	2	2	4	2	2	4	1.60	1.60	3.20	0.49	0.49	0.75
P36	Difficulty closing popup screen	1	2	3	2	3	5	3	2	5	4	4	8	2	2	4	2.40	2.60	5.00	1.02	0.80	1.67
P37	Delete an event	2	2	4	2	4	6	2	3	5	2	2	4	2	2	4	2.00	2.60	4.60	0.00	0.80	0.80
P38	Image of profiles and calming object	1	1	2	1	2	3	2	2	4	3	4	7	2	2	4	1.80	2.20	4.00	0.75	0.98	1.67
P39	Obligation of actions of different types of users	2	3	5	1	2	3	3	2	5	4	4	8	3	3	5	2.50	2.75	5.25	1.00	0.74	1.60
P40	Non-descriptive consultation type	2	2	4	1	3	4	3	2	5	3	3	6	4	4	8	2.60	2.80	5.40	1.02	0.75	1.50
P41	Confusion between the "New planning" button and the planning section.	2	2	4	3	4	7	3	2	5	4	4	8	4	4	8	3.20	3.20	6.40	0.75	0.98	1.62

P42	User profile has no calendar	2	2	4	0	2	2	2	2	4	4	4	8	4	4	8	2.40	2.80	5.20	1.50	0.98	2.40
P43	Intention of the communications notebook	1	2	3	0	1	1	3	2	5	4	4	8	4	4	8	2.40	2.60	5.00	1.62	1.20	2.76

Based on the standard deviations obtained in the criticism of the potential problems, we can mention that 8 potential problems (P4, P9, P13, P22, P33, P34, P42 and P43) have values of more than 2.06, which means that the evaluators differ on their opinions. These high values in the standard deviation are due to the fact that the evaluators that work in the ASD domain consider these 8 potential problems to be very critical for systems and/or applications designed for people with ASD, unlike the other evaluators, which assigned moderate values. Although these differences are large, we believe that these results help us to highlight the importance of having experts from the different knowledge areas (UX, ASD and both), since a potential problem that is considered mild or moderate by an UX expert, is considered serious for someone with knowledge in the ASD domain, and therefore should not be ignored.

2.3.4 Ranking of Potential Problems

Table EE shows the potential problems found, arranged in descending order based on the critical averages obtained.

Table EE. Ranking of Potential Problems on PlanTEA by Criticality

		Average		
ID	**Problem Definition**	**Severity**	**Frequency**	**Criticality**
P2	Options use iconography and do not include text that represents	3.25	4.00	7.25
P17	Difficulty and inconsistency in saving an event on a specific day	3.60	3.60	7.20
P6	Difficult pictogram movement in planning	3.80	3.20	7.00
P14	Elimination of progress when changing day	3.80	3.20	7.00
P16	Events visible out of date	3.80	3.20	7.00
P7	Confusing pictogram categories	3.40	3.40	6.80
P24	Too much information	3.20	3.40	6.60
P8	Difficulty removing a pictogram	3.60	2.80	6.40
P18	Scroll not evident in communication notebook box	3.00	3.40	6.40
P28	Confirm a schedule	3.20	3.20	6.40
P41	Confusion between the "New planning" button and the planning section.	3.20	3.20	6.40
P25	No customization of interface elements	2.80	3.40	6.20
P26	Lack of audio help in the user manual	3.00	3.20	6.20
P29	Make actions easier	3.00	3.20	6.20

P4	The "schedule" button does not schedule immediately	3.00	3.00	6.00
P15	Confusing and inconsistent event visibility	3.00	3.00	6.00
P30	Unexpected closing of the app	3.40	2.60	6.00
P19	Unclear and contradictory pictogram intensity	2.50	3.25	5.75
P3	It is not allowed to "schedule" without selecting the default time	2.80	2.80	5.60
P9	Step repetition to select pictograms from the "action" category	2.80	2.80	5.60
P13	Non-modifiable consultation type and time	2.60	3.00	5.60
P34	Lack of linguistic connectors	2.60	3.00	5.60
P20	Difficulty closing pictograms	2.80	2.60	5.40
P22	Unintuitive user manual	3.00	2.40	5.40
P40	Non-descriptive consultation type	2.60	2.80	5.40
P39	Obligation of actions of different types of users	2.50	2.75	5.25
P5	Schedule date and time are not displayed throughout the process	2.20	3.00	5.20
P23	Application responsiveness on different devices	2.80	2.40	5.20
P27	Actions carried out with unrepresentative icon	2.60	2.60	5.20
P33	Lack of welcome tour	3.00	2.20	5.20
P42	User profile has no calendar	2.40	2.80	5.20
P1	There is no differentiation between users and objects	2.60	2.40	5.00
P11	Hard to see error messages and confirmation of actions	2.40	2.60	5.00
P31	Unnecessary information	2.60	2.40	5.00
P36	Difficulty closing popup screen	2.40	2.60	5.00
P43	Intention of the communications notebook	2.40	2.60	5.00
P37	Delete an event	2.00	2.60	4.60
P10	Frame consistency for different types of pictograms	1.80	2.60	4.40
P32	User manual slow to load	2.20	2.20	4.40
P12	Activity and event icons are unclear	2.20	2.00	4.20

P21	Inconsistency and animations in entertainment pictograms and rewards	2.20	2.00	4.20
P38	Image of profiles and calming object	1.80	2.20	4.00
P35	Password modification icon	1.60	1.60	3.20

The results show that a total of 5 potential problems obtained a criticality value greater than 7.0 on a scale of 0-8. Potential problems P2 "options use iconography and do not include text representing them", P17 "difficult and inconsistency to save an event on a specific day", P6 "difficult movement of pictograms in planning", P14 "Deleted progress when changing a day" and P16 "Events visible outside the date", were considered by the evaluators as the most critical potential problems of the application. These potential problems should be considered a priority when updating the application to improve the user experience.

Table FF shows the potential problems found, arranged in descending order based on the severity averages obtained.

Table FF. Ranking of Potential Problems on PlanTEA by Severity

		Average		
ID	**Problem Definition**	**Severity**	**Frequency**	**Criticality**
P6	Difficult pictogram movement in planning	3.80	3.20	7.00
P14	Elimination of progress when changing day	3.80	3.20	7.00
P16	Events visible out of date	3.80	3.20	7.00
P8	Difficulty removing a pictogram	3.60	2.80	6.40
P17	Difficulty and inconsistency in saving an event on a specific day	3.60	3.60	7.20
P7	Confusing pictogram categories	3.40	3.40	6.80
P30	Unexpected closing of the app	3.40	2.60	6.00
P2	Options use iconography and do not include text that represents	3.25	4.00	7.25
P24	Too much information	3.20	3.40	6.60
P28	Confirm a schedule	3.20	3.20	6.40
P41	Confusion between the "New planning" button and the planning section.	3.20	3.20	6.40
P4	The "schedule" button does not schedule immediately	3.00	3.00	6.00
P15	Confusing and inconsistent event visibility	3.00	3.00	6.00
P18	Scroll not evident in communication notebook box	3.00	3.40	6.40

P22	Unintuitive user manual	3.00	2.40	5.40
P26	Lack of audio help in the user manual	3.00	3.20	6.20
P29	Make actions easier	3.00	3.20	6.20
P33	Lack of welcome tour	3.00	2.20	5.20
P3	It is not allowed to "schedule" without selecting the default time	2.80	2.80	5.60
P9	Step repetition to select pictograms from the "action" category	2.80	2.80	5.60
P20	Difficulty closing pictograms	2.80	2.60	5.40
P23	Application responsiveness on different devices	2.80	2.40	5.20
P25	No customization of interface elements	2.80	3.40	6.20
P1	There is no differentiation between users and objects	2.60	2.40	5.00
P13	Non-modifiable consultation type and time	2.60	3.00	5.60
P27	Actions carried out with unrepresentative icon	2.60	2.60	5.20
P31	Unnecessary information	2.60	2.40	5.00
P34	Lack of linguistic connectors	2.60	3.00	5.60
P40	Non-descriptive consultation type	2.60	2.80	5.40
P19	Unclear and contradictory pictogram intensity	2.50	3.25	5.75
P39	Obligation of actions of different types of users	2.50	2.75	5.25
P11	Hard to see error messages and confirmation of actions	2.40	2.60	5.00
P36	Difficulty closing popup screen	2.40	2.60	5.00
P42	User profile has no calendar	2.40	2.80	5.20
P43	Intention of the communications notebook	2.40	2.60	5.00
P5	Schedule date and time are not displayed throughout the process	2.20	3.00	5.20
P12	Activity and event icons are unclear	2.20	2.00	4.20
P21	Inconsistency and animations in entertainment pictograms and rewards	2.20	2.00	4.20
P32	User manual slow to load	2.20	2.20	4.40
P37	Delete an event	2.00	2.60	4.60

P10	Frame consistency for different types of pictograms	1.80	2.60	4.40
P38	Image of profiles and calming object	1.80	2.20	4.00
P35	Password modification icon	1.60	1.60	3.20

The results show that a total of 18 potential problems obtained a severity value greater than 3.0, on a scale of 0-4, where 5 potential problems obtained a severity value greater than 3.6. The potential problems P6 "difficult movement of pictograms in planning", P14 "Deleted progress when changing a day", P16 "Events visible outside the date", P8 "Difficulty to delete a pictogram" and P17 "Difficulty and inconsistency when storing an event on a specific day", were considered by the evaluators as the most harmful potential problems of the application.

Considering the potential problems with greater criticality and severity, we can mention that: (1) 80% of the potential problems within the top 5 criticalities are part of the top 5 severities (P17, P6, P14 and P16); (2) The potential problem P2 is considered the most critical, but it is 8th place in severity, since this potential problem was valued by the evaluators with a maximum score of 4 in its frequency; (3) The potential problem P8 is 4th place in the severity ranking and number 8 in the criticality ranking, because it was valued by the evaluators with a frequency score of 2.8, out of a maximum of 4.

2.4 Perception Questionnaire

After performing the inspection methods, property checklist and heuristic evaluation, the evaluators answered a perception questionnaire to know their perception after interacting with the application. The results show that:

- A total of 6 evaluators (60%) believe that the application helps the user during their interaction without feeling disoriented.
- 70% of the testers think that the interaction with the application is difficult.
- A total of 5 evaluators (50%) believes that the interactions they had with the app when trying to achieve their goals were ineffective.
- 50% of the evaluators believe that their satisfaction with the system was unsatisfactory.
- A total of 5 evaluators (50%) have a neutral opinion on whether the PlanTEA application should be recommended for planning medical appointments and communication with specialists.
- 40% of the evaluators strongly agree (4 evaluators), 10% agree (1 evaluator) and 20% have a neutral opinion (2 evaluators) that the app is attractive to users with ASD.
- 20% of the evaluators (70%) disagree (2 evaluators), 30% disagree (3 evaluators) and 20% have a neutral opinion (2 evaluators) that the application creates an environment of trust for the user with ASD.
- A total of 3 evaluators (30%) agree, 1 evaluator (10%) strongly agree, and 3 evaluators (30%) have a neutral opinion regarding that the elements of the application are ordered, structured coherently and are consistent throughout the interaction.
- A total of 6 evaluators (60%) agree that the application takes into account the needs of users with ASD.

- 60% of the evaluators agree that the application elements (including texts, icons, processes), as well as the interactions with these elements, are familiar and similar to those that can be found in real life.
- A total of 5 evaluators (50%) agree that the application is customizable.
- A total of 5 evaluators (50%) agree, and 4 evaluators (40%) have a neutral opinion about whether the application is designed taking into account the sensory characteristics of users with ASD (vision, hearing and touch).
- A total of 7 evaluators (70%) agree that the app keeps the attention of users with ASD.
- 70% of evaluators agree that the app manages time adequately.
- A total of 7 evaluators (70%) strongly disagree, 3 evaluators (30%) disagree, and 2 evaluators (20%) have a neutral opinion that the application avoids frustration in users with ASD during their interaction.

The evaluators emphasize the use of pictograms, the communication notebook, the usefulness and simplicity of the application. On the other hand, the evaluators emphasize the need to have a previous tutorial for using the application, to have more customizable elements and to make improvements when managing planifications.

3 User Tests

In order to evaluate the PlanTEA application with users with ASD, we have carried out a controlled observation with 7 participants with ASD level 1 [1], members of the AUTRADE group, at the AUTRADE premises.

3.1 Preliminary Questionnaire

Prior to carrying out the tasks with the PlanTEA application, the participants answered a preliminary questionnaire in order to find out their demographic information and previous experiences. The results obtained show that:

- A total of 2 participants identified as female and 5 as male.
- The age of the participants is between the range of 20-26 years, with the average age being 22.57.
- A total of 4 participants (57.14%) mention that they have never and/or almost never planned a medical consultation in advance.
- 57.14% of the participants (4 participants) declare that sometimes it is easy for them to communicate with the doctor during a medical consultation.
- A total of 4 participants (57.14%) mention that they have sometimes felt satisfied after a medical consultation.
- 85.71% of the participants state that they use tablets, mobile phones and/or computers every day of the week.
- A total of 6 participants (85.71%) mention that they never use applications designed for people with ASD.

3.2 Controlled Observation

The evaluation has been carried out in two sessions, where in the first one there have been 3 users and the second with 4 users. Additionally, it has had the support of two expert researchers in UX and ASD, and two professionals expert in ASD from AUTRADE [183].

The evaluation has been structured so that users with ASD feel comfortable and safe. For this, we have carried out the following steps:

1. The evaluation participants were contacted in advance of the day of application of the evaluation method.
2. The ASD professionals from AUTRADE provided guidelines to the researchers on the main personal characteristics of each of the participants, to be taken into account during the evaluation.
3. Prior to the execution of the evaluation, a set of textual instructions has been provided to the participants about the experiment, actions to be carried out and names of the research team, which was kept during the test as support material for the user in case you need it.
4. Each participant has been asked to read, consent to and respond to the confidentiality agreement and preliminary questionnaire documents (8 questions), accompanied by an AUTRADE professional.
5. The participants were escorted to the office where the researchers were located. This office was equipped with all the necessary equipment to carry out the evaluation (tablet with the PlanTEA application installed, camera that recorded the user's hands while interacting with the application, and instructions with the tasks to be carried out by the user in the application).
6. Finally, the participants have been asked to answer a perception questionnaire (17 questions) about the PlanTEA application, accompanied by an AUTRADE professional.

The results obtained in the questionnaires and tasks carried out by the participants are presented below.

3.2.1 Tasks Execution

A total of six tasks have been planned to be carried out in the PlanTEA application, however, only two of these tasks have been able to be carried out, due to an unforeseen error with the PlanTEA application related to the screen resolution that was not correctly adapted to the provided tablet size, so it was not possible to complete processes such as saving medical appointment schedules. Therefore, the test focused on analyzing the planning of medical appointments and identifying the “Calming object” in the application.

In appendix H the tasks and their respective instructions given to the participants are presented. The details of the tasks performed are presented below:

1. Schedule medical appointment to get vaccinated against the flu: task whose objective is that the user can plan his appointment to get vaccinated against the flu using the "scheduler" profile. Because the assignment of the event created to a specific day could not be saved, the creation of the event itself was considered a completed task. The estimated time for the task is 8 minutes.

2. Calming Object: task whose objective is for the user to be able to identify the "Calming Object" on the screen. To do this, the participant had to access the user profile. The estimated time for the task is 2 minutes.

The details and results of the evaluation by each of the participants are presented below.

3.2.2 First Participant

The results obtained with the first participant are:

- First task: In the first instance, the participant has searched for the options to plan events in the user profile. Positioned in the user's profile, the participant has had problems to “close” the selected pictograms. The participant confuses the “right” pictogram with the action of going back. Difficulty adding, removing or changing the order of the pictograms when planning an event.
- Second task: The user has successfully identified the calming object.

Additionally, it is highlighted that the participant has become overwhelmed and lost concentration due to his discomfort when interacting with the pictograms of the application. The user has taken approximately 31 minutes to complete all the requested tasks.

3.2.3 Second Participant

The results obtained with the second participant are:

- First task: The user believes that the scheduling of events should be done in the user's profile. The participant expresses his frustration when using the tablet, since he mentions that he is used to using computers and not tablets. Difficulty when selecting a category when planning, since the category must be pressed hard and for more seconds than normal to be able to access it. Difficulty interacting with the pictograms when planning events. Frustration due to the application not saving your information when going back in the tabs. The user has only added a pictogram to the created event sequence.
- Second task: The user has identified the calming object with difficulty, because for evaluation purposes an image of a ball has been assigned as a calming object, and mentions that this object does not calm him down.

On the other hand, the participant mentions that he has had difficulties creating the planning, since the application is “inaccurate”. The user has taken approximately 14 minutes to complete all the requested tasks.

3.2.4 Third Participant

The results obtained with the third participant are:

- First task: The user directly accesses the scheduler profile. It is believed that to interact with the pictograms you must click and not drag. Difficulty adding and removing pictograms when planning an event. Difficulties when differentiating a category or a pictogram that can be added to the sequence of the event to be created. Confusion with the “back” buttons, when planning an event, since there is a button to go back in the categories of the pictograms and by tabs.
- Second task: The user has successfully identified the calming object.

The participant mentions that in general it has had difficulties creating the planning. The user has taken approximately 17 minutes to complete all the requested tasks.

3.2.5 Fourth Participant

The results obtained with the fourth participant are:

- First task: The user directly accesses the scheduler profile. The participant had difficulty finding the option to add a new event. Difficulty adding, removing or changing the order of the pictograms when planning an event.
- Second task: It is believed that the user's profile can be accessed in the top option, in the planner profile, which has a "user" icon. The calming objects are mentioned to be the ball and the communication notebook. Attempts to interact with the calming object, ball, in the same way as creating an event in the scheduler profile. There is no interaction with the communications notebook.

The user has taken approximately 15 minutes to complete all the requested tasks.

3.2.6 Fifth Participant

The results obtained with the fifth participant are:

- First task: The participant directly accesses the planner profile. Confusion with the objectives of the button called "Plan" and "+ new planning". Difficulties to interact with the pictograms, since the pictograms are expected to be added to the sequence when clicking on it. By the time the user knows how to add the pictograms to the sequence, they have no problem removing them. In order to add a new element to the sequence, at the beginning of the sequence or in the middle, the user removes the pictograms that will be after (in position) related to the new pictogram to be added.
- Second task: The user has successfully identified the calming object; however, attempts are being made to perform more actions than are allowed by the application with the pictogram.

The user has taken approximately 14 minutes to complete all the requested tasks.

3.2.7 Sixth Participant

The results obtained with the sixth participant are:

- First task: The user directly accesses the scheduler profile. The message "No schedules available" makes the participant think that they cannot create a new schedule. Difficulty adding, removing, or changing the order of pictograms when planning an event. Once in the pictograms of a specific category, it is not understood how to return to the other categories. Confusion with the "back" buttons, when planning an event, since there is a button to go back in the categories of the pictograms and by tabs. Discomfort due to inaccuracy when selecting a pictogram. Once the sequence of the event to be created on the screen is complete, it is believed that no more pictograms can be added. The participant does not realize, before saving, that he must assign a name to the newly created schedule.
- Second task: The user has indicated that the communication notebook is the calming object, however, once they interact with it, the participant clearly identifies it as a communication notebook. The tranquilizing object has not been identified.

The participant mentions that it would be good to change the name of the "+ new planning" button by adding the word "steps", such as: "planning steps". Additionally, the user highlights that the texts of the application, such as the section to select the time, are cut off due to the resolution of the application. The user has taken approximately 19 minutes to complete all the requested tasks.

3.2.8 Seventh Participant

The results obtained with the seventh participant are:

- First task: The user directly accesses the scheduler profile. The title "New event" is pressed in order to create a new schedule. The participant tries to schedule a new event without assigning a time and type of consultation. Difficulty in selecting the categories of the pictograms. Difficulty adding, removing or changing the order of the pictograms when planning an event. Uncertainty once the new schedule is created, since the user does not understand why the new schedule is not reflected in the calendar.
- Second task: Initially, you interact with the communication notebook. The participant interacts with the calming object, but it causes him stress, since he expected a greater interaction with it. The user mentions not identifying any reassuring objects.

The user has taken approximately 17 minutes to complete all the requested tasks.

3.3 Perception Questionnaire

After performing each of the tasks requested in the PlanTEA application, the participants have been asked to answer a perception questionnaire, in order to know their perception after interacting with the application. The results show that:

- A total of 4 participants (57.14%) have a neutral opinion about the difficulty in completing the indicated tasks.
- 57.14% (4 participants) of the participants have a neutral opinion about the difficulty of finding the required information.
- A total of 3 participants (42.85%) believe that the application has rarely provided them with enough information to perform the indicated tasks.
- 42.85% of the participants (3 participants) have a neutral opinion about whether the information provided by the application is understandable. On the other hand, 28.57% of the participants (2 participants) state that the information provided by the application is not very understandable.
- A total of 3 participants (42.85%) have a neutral opinion about whether they have felt helped/guided by the application when planning medical consultations. On the other hand, 3 participants (42.85%) mention that they fully agree that they have felt helped/guided by the application when planning medical consultations.
- A total of 5 participants (71.42%) mention that it has been difficult for them to use the application.
- Participants have mixed opinions about how overwhelming the information provided by the app could or could not be. A total of 2 participants (28.57%) mention that they definitely have not felt overwhelmed, and 2 participants (28.57%) state that they have felt somewhat overwhelmed.

- 71.42% of the participants (5 participants) mention that the images, icons and symbols used in the application are definitely easy to understand.
- Participants have mixed opinions about the customization options for aspects of the application. A total of 3 participants (42.85%) mention that the application is not very customizable, and 3 participants (42.85%) state that customizing aspects of the application is definitely allowed.
- A total of 3 participants (42.85%) strongly disagree and 3 participants (42.85%) disagree that some visual and/or sound element of the application has bothered them.
- A total of 2 participants (28.57%) strongly disagree and 2 participants (28.57%) disagree about whether they have felt distracted while interacting with the application.
- 42.85% of the participants (3 participants) have a neutral opinion about whether the application has helped them to solve the errors made during their interaction.
- A total of 2 participants (28.57%) strongly agree and 2 participants (28.57%) agree if they would use the PlanTEA application again to plan their next medical visits.
- The participants highlighted that they liked the PlanTEA application: (1) the facility to better organize themselves, (2) plan medical consultations by themselves, (3) the use of pictograms.
- On the other hand, they mention that they did not like the PlanTEA application: (1) the delay in responding to their actions, (2) the difficulty when interacting with the elements, (3) the non-intuitive and difficult to visualize elements.

4 Results and Recommendations

After applying the methodology to evaluate the user experience [12] on the PlanTEA application, we can conclude that:

- It is important to improve the application in the aspects belonging to the engaging, structured and frustration-free categories specified in the inspection with the property checklist (appendix F). Providing timely feedback when performing an action in the app, for example when creating a new schedule, could help improve app appeal and engagement. Maintaining consistency in the information presented and the way of interacting with the elements of the application would help to improve the structure of the application. In addition, providing readable and structured documentation, messages, and error recovery options will help improve the frustration-free system.
- The 43 potential problems found by the evaluators must be addressed, prioritizing the potential problems with greater criticality and severity. For the main potential problems, we present the following recommendations:
    - P2 “Options use iconography and do not include text that they represent”: Information must be provided about the elements present on the screen, for example, include a text saying “communications notebook” under said object/button in the user profile.
    - P17 "Difficulty and inconsistency in saving an event on a specific day": When creating a new schedule, it is not assigned to the day and time previously

selected in the application. It is suggested that the selection of schedules available in the application be done through a checkbox or some similar element that helps the user visually identify that they must select it to be assigned on the desired day.

- P6 "Difficult movement of pictograms in planning": It is recommended that when selecting a pictogram in the application, it provides visual feedback to the user, such as highlighting the edges of the pictogram to indicate that it has been correctly selected for movement, similar to the behavior of apps in a tablet menu when long pressing and then rearranging them.
- P14 “Delete progress on day change”: It is suggested that the system warn and wait for a response from the user before changing to a different day on the calendar.
- P16 “Visible events outside of the date”: It is recommended that the application visually identify medical appointments on dates already in the past in a distinctive way. Verifying the current date of the tablet with the date of the schedules assigned in the calendar, would allow discriminating the schedules allowed to interact.
- P8 "Difficulty removing a pictogram": It is suggested to exchange the positions of the sections (available pictograms and green rectangle with the sequence with the added pictograms) in the creation tab of a new plan, leaving the sequence of pictograms at the bottom from the screen. When carrying out this exchange, eliminating a pictogram from the sequence is more natural, since by moving said pictogram up it can be understood that said pictogram is returned to its origin. An alternative to deleting the pictograms can also be offered by adding a button with a “delete” icon that appears after long-pressing on the pictogram to select it.

- The results obtained with the user test confirm the importance of solving the potential problems identified in the inspection methods. Potential problems such as (1) the difficulties to interact with the pictograms, (2) the creation and assignment of a medical appointment in the calendar is not intuitive and (3) the little feedback from the application on the elements present on the screen, are potential problems that were confirmed by the results obtained in controlled observation. Additionally, this test highlights (1) the importance of providing clear messages free of interpretations, (2) the need to differentiate between the categories of pictograms and the pictograms available to be added to the sequence and (3) the need to clarify the intention of the “back” buttons, for which the users presented difficulties in correctly identifying.

APPENDIX J

The proposed methodology [12] has been applied to evaluate the UX on the website www.expedia.com [182]. Expedia is an online travel agency that allows you to buy plane flights, rent accommodation, vehicles, cruises, vacation packages and amusement parks.

1 Expedia Case Study

To evaluate the UX of the expedia.com website, the following evaluation methods have been applied: property checklist [151], group-based expert walkthrough [152], perspective-based inspection [153] and field observation [151]. For the application of these evaluation methods, there has been a total of 11 experts (property checklist 4 experts, group-based expert walkthrough 4 experts, perspective-based inspection 3 experts) with knowledge of UX, ASD and both areas, and the participation of 4 adults diagnosed with ASD level 1 for field observation.

Below is a detail of what was done and the results obtained in each of the evaluation methods applied to evaluate the UX of expedia.com.

2 Inspections

To evaluate the UX of the website www.expedia.com, three inspection methods have been carried out: property checklist, perspective-based inspection and group-based expert walkthrough. For each evaluation method we have requested the help of experts with knowledge in UX, ASD and/or in both areas.

The evaluators have been sent by email the instructions for the evaluation to be carried out and an excel file that includes instructions, preliminary and perception questionnaires, and formatted sheets to complete the required information depending on the inspection method to be carried out. The structure of the excel file is presented below:

1. Presentation of the evaluation to be carried out.
2. Preliminary questionnaire, which contains a total of 11 questions focused on knowing about the knowledge and previous experiences of the evaluators.
3. Formatted spreadsheets to facilitate inspection.
4. Perception questionnaire, which presents 17 questions focused on knowing the perception of the evaluator after interacting with the expedia website.

For the property checklist evaluation, they have been provided with the property checklist specification, made up of 9 categories and 26 items. The evaluators, then interacting with the expedia.com website, had to evaluate compliance with each of the items presented in the property checklist through a scale of 1-5 (1: Totally not complied - 5: Totally complied), and optionally provide comments/observations on each item.

For the perspective-based inspection evaluation, a spreadsheet has been provided, which details: (1) specification of the scenario to be carried out on the expedia.com website, (2) assessment scales for potential problems found, delivering a description, range, and scale for severity, frequency, and criticality, (3) specification of the perspective assigned to the evaluator (novice, expert, and/or error handling), and (4) specification of the tasks to be

performed and guiding questions for each task, which the evaluators had to complete and document each identified potential problem after interacting with the expedia website. For each potential problem, the evaluators had to provide a definition, explanation, identify the path followed to find the problem, an image with the problem, and assign a frequency and severity according to their criteria.

For the group-based expert walkthrough evaluation, a spreadsheet has been provided, detailing: (1) specification of the scenario to be carried out on the expedia.com website, (2) assessment scales for potential problems encountered, providing a description, range and scale for severity, frequency and criticality, and (3) specification of the tasks to be carried out, that the evaluators had to complete and document each identified potential problem after interacting with the expedia website. For each potential problem, the evaluators had to provide a definition, explanation, and assign a frequency and severity according to their criteria.

A common scenario and three common tasks have been proposed for the perspective-based inspection and group-based expert walkthrough methods. The scenario and tasks are:

- Scenario: Three adults in company with two minors (1 year old and 10 years old) plan to travel to Barcelona (Spain) from February 20 to March 4, 2023. Accommodation must be found near the center of the city and have a kitchen enabled for its use. Two rooms are required, in one of them there will be 2 adults and a child under 1 year of age, and in the other room an adult and a child under 10 years of age. Consider that the flights must be direct and that the starting point is the Arturo Merino Benitez airport (SCL), Santiago de Chile.
- Tasks: (1) entry of trip parameters (dates, passengers, places, etc.), (2) find accommodation and (3) find a round trip flight.

The results obtained in the questionnaires and inspection methods carried out are presented below.

2.1 Preliminary Questionnaire

The 11 Expert profiles include PhD students, UX researchers, IT experts with UX/Usability expertise, and ASD experts, as well as the support of a speech therapist with practical experience in working with people with ASD. Some of these experts have experience in both UX/Usability and ASD. As a result, we have obtained the following information:

- A total of 9 experts (81.81%) previously knew UX and Usability concepts.
- All the experts were previously aware of the concept of TEA.
- A total of 2 experts (18.18%) have previously used applications and/or systems designed for people with ASD.
- 81.81% of the experts (9 evaluators) have previously used applications or websites to book hotels, flights or rent vehicles. Some of the applications and/or websites used by experts are: Google Flights, Booking, Hostelworld, Airbnb, among others.

2.2 Property Checklist

In order to evaluate the expedia.com website, we have made an adaptation of our property checklist proposal to evaluate the UX for people with ASD [176]. This adaptation consists

of a compact version [176], which is made up of 9 categories and a total of 26 items. The adaptation of the property checklist used is presented in appendix F.

A total of 4 expert evaluators with knowledge in UX, ASD and both areas have evaluated the expedia.com website using the adapted property checklist.

Considering the answers obtained by the evaluators and the calculation considerations raised in our methodology [12], we can conclude that the percentage of satisfaction of the expedia.com website is 54.5%.

The percentages of satisfaction obtained by each category, as specified in our property checklist proposal [176], are presented in Table GG.

Table GG. Expedia Satisfaction Percentage

Category Name	Satisfaction Percentage
Engaging	56.0%
Predictable	60.0%
Structured	56.0%
Interactive	58.7%
Generalizable	68.0%
Customizable	28.0%
Sense-aware	56.8%
Attention Retaining	50.7%
Frustration Free	56.0%
Average Satisfaction	**54.5%**

Graphing the information obtained in Table GG, as proposed in the methodology [12], Figure J is obtained as a result.

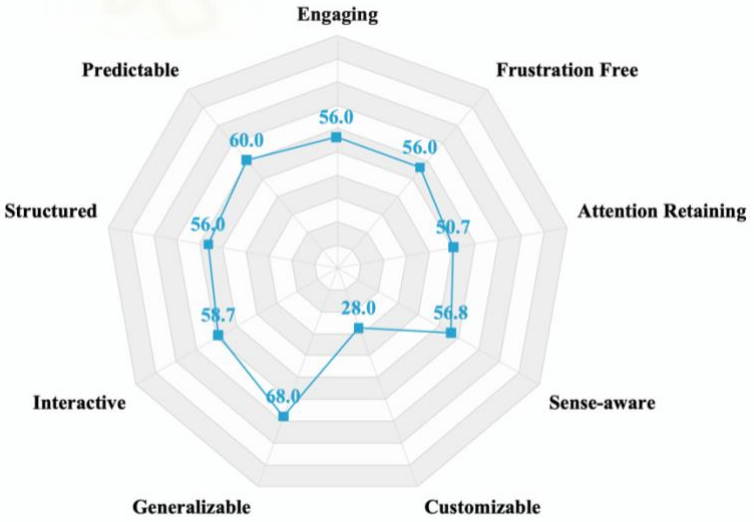


Figure J. Expedia satisfaction percentage per category

The highest percentages of satisfaction are presented in the generalizable and predictable categories, with 68% and 60% respectively.

Even though the generalizable category has been valued with the highest score by the evaluators, the comments mention that: (1) "there are occasions when the elements on the

screen do not resemble elements learned in similar applications, which can lead to confusion" and (2) “there is a lack of iconography to help reading”.

Regarding the predictable category, the evaluators have commented that: (1) "it is predictable for a person who frequents similar sites, but for someone new it can be confusing" and (2) "the site allows you to go back in the actions without forgetting the information provided”. However, it is mentioned that “the flow of the site is sometimes cut off when opening new tabs” and “when changing the currency used, the search parameters performed are deleted”.

On the other hand, the lowest percentages of satisfaction are shown in the customizable and attention retaining categories, with 28% and 50.7% respectively.

Reviewers have commented on the customizable category that: (1) “during my interaction with the website I did not see any customization options, even though it says they comply with accessibility standards” and (2) “sometimes the website does not allow you to change the currency used.

Regarding the attention retaining category, the evaluators have commented that: (1) "when performing a search, such as when looking for accommodation, the website has long waiting times, without feedback on said search and waiting", (2) “there is excess information throughout the website, which can be distracting” and (3) “the website opens new tabs without notice”.

The 9 categories presented were rated with satisfaction rates lower than 68% by the evaluators. The generalizability and predictability of the website is positively highlighted; however, the comments of the evaluators highlight negative aspects in said categories. On the other hand, the need to have customization options and to moderate elements that help improve user attention is highlighted. It is necessary to address each of the categories, especially the customizable and attention retaining categories, in order to improve the UX when interacting with the website.

2.3 Perspective-based Inspection

Based on what was suggested by Zhang et. at [153] three perspectives were used to assess the UX of the expedia.com website. The perspectives used are:

- Novice ASD user, representing users with ASD who have little or no knowledge of expedia and similar sites.
- Expert user with ASD, representing expert users on the expedia website and similar sites. An expert user is someone who: (1) can complete each task easily and efficiently, (2) can customize the website to behave the way it wants it to, and (3) use advanced functionality or features of the website to be more productive.
- Error Handling User with ASD, which represents users with ASD with errors caused by some action on the website, and who also needs to resolve said errors. For the error handling user is important: (1) to minimize the chances of self-inflicted errors, (2) that the interface should help it understand the problem when errors occur, (3) that the interface helps recover from errors and (4) that system errors are handled appropriately.

For each proposed perspective there was 1 expert evaluator with knowledge of UX and ASD. The evaluator profiles include UX researchers, with knowledge of ASD, and a speech-language therapist with practical knowledge of ASD.
For each proposed task and proposed perspective, a set of guidelines was provided to the experts to help the evaluators find potential problems on the expedia website. The guiding questions were created taking into account the 9 UX factors proposed in previous works [11]. If the question can be answered with a "no", it implies that a potential problem has been detected on the website. Each of the guide questions provided to the evaluators is presented in appendix J.

To carry out the perspective-based inspection evaluation, the evaluators detailed the potential problems found after interacting with the expedia website, considering the scenario, tasks and guidelines given. The evaluators were asked to identify at least 10 potential problems. For each potential problem found, the evaluator provides a definition, comments and/or explanations about the identified problem, the path followed to find the potential problem, example image and assignment of the severity and frequency scales (see Table N).

2.3.1 Potential Problems Found

For each proposed perspective, a set of potential problems were found. The potential problems encountered by each proposed perspective are detailed below (novice user with ASD, expert user with ASD, and error handling user with ASD).

2.3.1.1 Novice user with ASD perspective

Table HH presents the 15 potential problems found by the evaluator.

Table HH. Potential Problems Found by Novice User with ASD

ID	Problem Definition	Comments and Explanation	Path to get to the problem
C1	Options with differences	When the search is performed, the option to enter a destination appears again, but it does not necessarily coincide with the option of the place (In the example, Barcelona, Barcelona, Catalonia, Spain appears) and the option with the destination icon omits the 2nd Barcelona, causing confusion)	Home
C2	Screen instructions	There is very little amount of filling or screen instructions. Filling is quite intuitive.	Home
C3	Selection is not thought for people with ASD	Although it has visual support with representative icons, it does not offer auditory or tactile options	Home
C4	Feedback on the screen	Not all the accommodation options show the selection of filters we have chosen, so we need to enter the accommodation to verify it.	Accommodation
C5	Clear and simple accommodation	I feel that a lot of information is displayed on the screen, apart from the images about the accommodation, the selection of filters is too intrusive when presenting the information.	Accommodation

C6	Selection of accommodation parameters not thought of for people with ASD	This section shows a lot of data and information, without considering tactile or auditory support.	Accommodation
C7	Accommodation page with too many distractions	When entering the accommodation page, many small messages appear with a variety of colors that tend to distract from the search and not simplify	Accommodation
C8	Problems to confirm availability	When selecting an accommodation, an option to see availability appears, which doesn't lead to any frustration	Accommodation
C9	Missing Clear identification of flights	To search for a flight, one of the options is necessarily to enter an accommodation, where flight options appear later. There are options of value 0. Which causes confusion and strangeness	Flights
C10	Flight information	The information about the flights is too small. It does not emphasize what is important	Flights
C11	Simple and consistent flights	The value of the flight is in dollars, which changes the currency used at the time of choosing the accommodation	Flights
C12	Flights page without help	This section again shows that there is no tactile or auditory support	Flights
C13	Distracting elements in flights	The flights page has the necessary information, but many elements appear within the filters that, instead of helping, distract the searcher	Flights
C14	Page is slow to load	The page takes time to load but it goes blank and doesn't show support for the timeout or if it's still working fine	Flights
C15	Errors in search	When an error is presented, it does not specify the reason and lets us run the search again.	Flights

2.3.1.2 Expert user with ASD perspective

Table II presents the 8 potential problems found by the evaluator.

Table II. Potential Problems Found by Expert User with ASD

ID	Problem Definition	Comments and Explanation	Path to get to the problem
I1	Red alerts appear suddenly	When defining the people who will be in each room, when pressing the button with a "+" for the "Children" or "Babies" section, a red box suddenly appears asking to indicate the ages of the children	Home
I2	High response time	When the "Direct flights only" option is checked and the "Search" button is pressed, the website reloads the options according to the filter, but this process takes longer than expected.	Accommodation

I3	The font size is not correct	For certain sections, the system uses a font size that can make it difficult to read information important to choosing a trip.	Accommodation
I4	The site offers options that do not meet the required requirements	When searching for accommodation, the website offers options that do not accommodate the selected ones, such as the number of rooms and people.	Accommodation
I5	Surprise pop-up	When selecting a flight, a pop-up appears quickly which can be stressful.	Flights
I6	Unclear information	When checking the details of the trip, a message appears informing about a change in the fare without giving further explanation.	Flights
I7	Unexplained details	The system notifies a section that is "Rate: Level" without giving further details of what this means.	Flights
I8	Unclear flight details	The system provides vague information about the flight, including a red number near the time.	Flights

2.3.1.3 Error handling user with ASD perspective

Table JJ presents the 11 potential problems found by the evaluator.

Table JJ. Potential Problems Found by Error Handling User with ASD

ID	Problem Definition	Comments and Explanation	Path to get to the problem
J1	Invasive form control	The announcement of "enter the age of the children" is somewhat intrusive. It is generated ahead of time.	Home
J2	Detailed breakdown by room	It seems irrelevant to "break down" the adult/child separation detail in the rooms. I imagine this is a family decision, and not part of the logic of the system. This should be enough to indicate the number of rooms required.	Home
J3	Age input in detailed breakdown by room	In the same scenario as above: If the age is not selected, there is no additional "movement" or gesture to indicate that an age of the child is missing. - Since this behavior does not exist in the control, we can lose time or assume that the site "hangs".	Home
J4	Destination results - Similar names	The difference between the available options is unclear. Although we can assume that an airplane icon refers to an airport, this is not the case with the rest of the results.	Home
J5	"Direct flights" filter	It is strange that the option "only direct flights" is in another section; Considering that there is a section of classic filters a little further down.	Accommodation
J6	Dynamic results with filters	The behavior of the results of the accommodation is not very predictable. Although it is sometimes perceived that the	Accommodation

		filters update automatically, this is not the case. Selecting a specific filter "reloads" all the results. This can cause errors on more unstable connections or confuse the user.	
J7	Information of ticket details on the map	Results when the card is shown. The behavior is as expected, but the service total is high. It is explained that it is the combination of tickets + accommodation. But I think it is necessary to outline with more details.	Accommodation
J8	Icons when selecting a room.	When different rooms are displayed, it implies different prices. However, the iconography used is not clear. Is it (-) a lower price?	Accommodation
J9	Information about destination airports	Confusing messages regarding the airport. The system asks to confirm the destination airport. However, explanations of the motive are on a secondary level of importance.	Flights
J10	Cost +0	Choice of flights +0. I imagine this refers to the fact that, when selecting a complete package in the previous section, this flight is already considered. But it's strange that this type of information appears so far into the process. Obviously, this is prone to user error.	Flights
J11	Total values	There was always talk of prices per person. Unfortunately, the total value is only displayed at the end of the simulation.	Flights

A total of 34 potential problems were found, taking into account the potential problems found by the evaluators in each of the proposed perspectives (novice user with ASD, expert user with ASD and error handling user with ASD). Of all the potential problems found by the evaluators, only 3 potential problems were repeated. We believe that a greater variety of potential problems was achieved thanks to the use of different perspectives.

2.3.2 Grades assigned by evaluators ranked by criticality

2.3.2.1 Novice user with ASD perspective

Table KK presents the list of potential problems found, with their respective assignments of severity, frequency and criticality (see Table N), arranged in descending order of criticality.

Table KK. Grades Assigned by Novice User Ranked by Criticality

ID	Problem Definition	Severity	Frequency	Criticality
C11	Simple and consistent flights	4	4	8
C2	Screen instructions	3	4	7
C5	Clear and simple accommodation	3	4	7
C9	Missing Clear identification of flights	3	4	7
C3	Selection is not thought for people with ASD	2	4	6
C6	Selection of accommodation parameters not thought of for people with ASD	2	4	6
C10	Flight information	2	4	6

C12	Flights page without help	2	4	6
C13	Distracting elements in flights	2	4	6
C4	Feedback on the screen	2	3	5
C7	Accommodation page with too many distractions	2	3	5
C14	Page is slow to load	2	3	5
C8	Problems to confirm availability	3	2	5
C1	Options with differences	2	2	4
C15	Errors in search	2	2	4

The results show that a total of 4 potential problems obtained a criticality value greater than 7, on a scale of 0-8. The potential problems C11 "Simple and consistent flights", C2 "On-screen instructions", C5 "Clear and simple accommodation" and C9 "Clear identification of flights", were considered the most critical potential problems of the website from the perspective of a novice user with ASD.

Through the identification of the most critical potential problems, from the perspective of a novice user with ASD, we can conclude that it is important to provide consistency throughout the interaction, not to overload with information, and to provide timely and specific feedback, in order to generate a good UX to people with ASD.

2.3.2.2 Expert user with ASD perspective

Table LL presents the list of potential problems found, with their respective assignments of severity, frequency and criticality (see Table N), arranged in descending order of criticality.

Table LL. Grades Assigned by Expert User Ranked by Criticality

ID	Problem Definition	Severity	Frequency	Criticality
I2	High response time	2	4	6
I4	The site offers options that do not meet the required requirements	2	4	6
I1	Red alerts appear suddenly	1	4	5
I3	The font size is not correct	1	4	5
I5	Surprise pop-up	1	4	5
I7	Unexplained details	1	4	5
I8	Unclear flight details	1	4	5
I6	Unclear information	1	1	2

The results show that a total of 2 potential problems obtained a criticality value equal to 6, on a scale of 0-8. The potential problems I2 "Long response time" and I4 "The website offers options that do not meet the requested requirements" were considered the most critical potential problems of the website from the perspective of an expert user with ASD. Through the identification of the most critical potential problems, from the perspective of an expert user with ASD, we can conclude that it is important not to have delays and deliver results according to the search performed, to have a good UX for people with ASD.

2.3.2.3 Error handling user with ASD perspective

Table MM presents the list of potential problems found, with their respective assignments of severity, frequency, and criticality (see Table N), in descending order by criticality.

Table MM. Grades Assigned by Error Handling User Ranked by Criticality

ID	Problem Definition	Severity	Frequency	Criticality
J4	Destination results - Similar names	3	2	5
J7	Information of ticket details on the map	3	2	5
J10	Cost +0	3	2	5
J1	Invasive form control	3	1	4
J2	Detailed breakdown by room	3	1	4
J6	Dynamic results with filters	2	2	4
J8	Icons when selecting a room.	3	1	4
J9	Information about destination airports	3	1	4
J11	Total values	3	1	4
J3	Age input in detailed breakdown by room	2	1	3
J5	"Direct flights" filter	2	1	3

The results show that a total of 3 potential problems obtained a criticality value equal to 5, on a scale of 0-8. The potential problems J4 “Destination results - Similar names”, J7 “Missing details of tickets on map” and J10 “Cost +0”, were considered the most critical potential problems of the website according to the perspective of an error handling user with ASD. Through the most critical potential problems, identified from the perspective of error handling user with ASD, we can conclude that it is important to provide better clarity between the options provided by the website (including the use of icons) and to provide explicit details of the information delivered to users, to generate a good UX for people with ASD.

The potential problems identified as most critical by each of the perspectives should be considered as a priority when providing a good UX to users with ASD.

2.4 Group-Based Expert Walkthrough

The group-based expert walkthrough method was used to inspect the system and identify potential problems through the expert judgment of 4 evaluators with experience in UX and ASD. Carrying out the inspection as a group makes it easy to include ASD experts, who may not necessarily have UX experience, in the testing process, so that more issues relevant to people with ASD can be found with their support.

For the execution of this method, 4 experts were used, as well as a fifth expert with experience in UX and ASD who acted as the leader and guided the other evaluators. The evaluator profiles include 3 experts in UX and ASD, and a speech therapist with practical knowledge in ASD. The evaluators met at the same physical location at a time agreed upon by all.

The evaluation consisted of two phases, which were repeated for each of the 3 tasks planned for the proposed scenario.

- Guided interaction by the evaluation leader with the expedia.com website, considering the proposed scenario and tasks, during which each evaluator individually documented potential problems, including an assignment of frequency and severity to each problem.
- The leader again guides the evaluators through the proposed scenario and tasks, during which the evaluators present and discuss out loud the potential problems

identified as a group. During this process, the potential problems are consolidated, as well as their severity and frequency is agreed upon by all the evaluators.

2.4.1 Potential Problems Found

After performing the group-based expert walkthrough, a total of 72 potential usability problems were identified, including their severity, frequency and criticality, which were discussed and consolidated among all the evaluators during the work session. Table NN presents all the problems found, separated by each of the 3 tasks performed.

Table NN. Potential Problems Found in Group-Based Expert Walkthrough

ID	Task	Problem Definition	Comments and Explanation
G1	Task 1	Origin and destination in reverse order on the main screen	When accommodation is selected, the origin and destination of the journey appear in reverse order of the usual flow. Destination appears first and source second.
G2	Task 1	Unclear and specific tab target	The purpose of each tab on the main page seems unclear, as each tab is capable of multitasking. The "packages" tab should be the only one that allows you to search for multiple items at once, and the others only focus on "accommodation" or "flights" without being able to add the other items to it.
G3	Task 1	Unnecessary information about minor passengers	Entering the exact age of the children is considered unnecessary and too specific and intrusive. This information must only be requested during check-in.
G4	Task 1	Entering children's information causes page expansion	When children and their ages are entered when searching, the page expands indefinitely as entries are added. Adding this information becomes confusing and irrelevant.
G5	Task 1	Entering a new room is confusing	It's not intuitive to add new rooms after people have signed up. It is confusing that when a new room is added, all passengers are assigned to the first room.
G6	Task 1	Button color is confusing	The buttons to remove items in the flight settings should be red, as is common on these sites. This can lead to confusion.
G7	Task 1	Unnatural eyelash arrangement	The order of the tabs on the main page is not natural considering the page options. Since the page allows you to create "packages" in all searches, the "packages" tab should be the main one.
G8	Task 1	Confusing button color	When a button is selected, it is not obvious that it has been selected due to the subtle color change.
G9	Task 1	"Baby" appears in rooms, which does not appear in the other menu	In certain tabs, the search parameter "baby" is added. This is inconsistent with the use of "child" in other tabs.
G10	Task 1	"Where will the baby sit?" must clearly indicate that it refers to the flight	When a "baby" is added, an open question is displayed indicating "where will the baby sit?". This question is not clear about the vehicle or room it refers to, so it can be confusing.

G11	Task 1	Flight year is not visible when needed	When selecting flight dates, the year is not displayed in the search window, which can be confusing and you need to remember information.
G12	Task 1	Unclear calendar behavior	When selecting flight dates, it is not clear that the calendar populates both date entries with the same calendar. It is also difficult to distinguish the selected start and end date as both use the same symbols and colors.
G13	Task 1	Advertisement with confusing messages	On the main screen there are ads that say "See Savings". This is unclear and confusing.
G14	Task 1	Message with strong colors	The "Indicate the age" message that appears when adding children is brightly colored and can be distracting.
G15	Task 1	Redundant message	When entering the website, a message is displayed stating "Welcome to Expedia" this is redundant as the same message is displayed twice.
G16	Task 1	Unclear the ability to add accommodations	It is not clear that when searching for flights, it is possible to add accommodation in future steps of the process.
G17	Task 1	Little clarity when cars or accommodations are added	It is not explicit that a car or accommodation can really be added when looking for packages.
G18	Task 1	Not explicit first class	When choosing first class, it is not clear whether it is for cars, accommodation or flights.
G19	Task 1	Room text is illegible and inconsistent	The text "rooms" is too small and its location is not consistent with the rest of the search options.
G20	Task 1	Intrusive ads	The ads presented on the main page are too big and flashy, which can distract from the search objective.
G21	Task 1	Only last room can be deleted	When deleting rooms, it is only possible to delete the last added room. This is inconvenient and can lead to mistakes or redoing tasks.
G22	Task 1	Confusion when adding more than one package.	Adding packages can cause confusion if you don't specify that more than one can be selected. Knowledge about the page is required to be able to add them.
G23	Task 1	Missing icons	Most of the site is presented in words. Adding representative icons can make many of the site's options easier to read.
G24	Task 1	Hard to see help symbol	Warnings when adding room data are displayed as an error for the first room, when the warning matches another room, which can cause confusion.
G25	Task 1	Hard to see help symbol	The help symbol is very small on the side of the page in case you need it. It also inconsistently disappears from some pages.
G26	Task 1	Inconsistent documentation link	When looking for help on "age rules", the link leads to general help and not to the specific one required by the user.
G27	Task 2	Excess information in accommodation search	The accommodation page contains too much information and images that can be distracting.

G28	Task 2	Unnecessary information	The accommodation page shows information regarding flights, which we consider irrelevant as we are focused on the search for accommodation.
G29	Task 2	Stressful messages	Messages are displayed encouraging you to buy as "not many rooms left", this can be stressful.
G30	Task 2	Non-fixed filters	The filters are not fixed to the screen, which complicates their use.
G31	Task 2	Confusing text about the amount of offers	The text on the screen indicates that "thousands of package offers" are being searched, which is not necessarily true and can lead to confusion.
G32	Task 2	Redundant and unclear filters	The "Type of trip" filter (LGBTQ, Business) seems redundant, the criteria to be used in these filters is not clear.
G33	Task 2	Unclear room capacity	The website shows that there are two rooms available for 6 people, but does not specify the capacity of these rooms separately.
G34	Task 2	Confusing message about refunds	The message "fully refundable property" is displayed, this is confusing as it is not clear whether it is the reservation or the property that is being refunded.
G35	Task 2	Inconsistent change of site language	When selecting a property, the website language is automatically changed to English, which is confusing and inconsistent.
G36	Task 2	Unclear how to close photos	When viewing photos of the properties, it is not clear how you can go back from this screen.
G37	Task 2	Unclear property rating	When viewing a property, it is not clear what the criteria are for the rating offered for the property.
G38	Task 2	Unclear accommodation stars	When viewing a property, it is not clear what the stars under the name of the accommodation mean.
G39	Task 2	Repeated information in accommodation	When viewing an accommodation, information is repeated in several sections, such as the location map appearing more than once.
G40	Task 2	Little clarity in accommodation prices	When the final price of a stay is shown, it is not clear whether it is per person, per room or the total.
G41	Task 2	Too many customization parameters	When searching for a host, many customization parameters are displayed which can be overwhelming, confusing and redundant.
G42	Task 2	Results do not match search parameters	When you search for an accommodation, many of the search results presented do not necessarily match the selected search parameters.
G43	Task 2	Prior knowledge of the user is assumed	When searching for trips, it is assumed that the user knows the city and its places and zones, which is not necessarily the case.
G44	Task 2	Multiple ways to achieve the same result	There are several ways to arrive at the same search and host result, which is inconsistent.
G45	Task 2	Inconsistency in font size	The accommodation titles appear in different font sizes, which are inconsistent.

G46	Task 2	Missing information to see compliance with search parameters	It is necessary to review the details of the rooms to see that the search parameters have actually been considered.
G47	Task 2	"VIP access" is confusing	When viewing accommodations, a tag called "VIP Access" is displayed, it is not clear what the purpose or criteria of this distinction is.
G48	Task 2	Very Small Map	The map shown to see the location of an accommodation is very small. It is important to recognize the spatial location of the accommodation.
G49	Task 2	Unintelligible text in accommodations	When searching for accommodation, the text: "We have 6 left" is displayed, which is not understandable and can be confusing.
G50	Task 2	Insufficient zone filters	When filtering by location, it is not possible to select more than one area, which limits the search options.
G51	Task 2	Low priority property name filter	Search by property name should be a filter with higher importance and should be displayed as a main filter.
G52	Task 2	Unclear "Select your unit" text	When selecting accommodation, the text "Select your unit" is used. It is not clear what is meant by "unit" in this context and can be confusing.
G53	Task 2	Room is selected by default	The system chooses a default room without asking the user first, which limits the user's freedom.
G54	Task 2	Text "per night" not very visible when looking at prices	The text "per night" accompanying the room prices is very small and difficult to see clearly.
G55	Task 2	Searches do not explicitly show distance to the city center	When performing a search for accommodation without filtering by distance, it is not possible to explicitly see the distance to the center of the city, this information is important.
G56	Task 2	It is not possible to change distance metric	You cannot change the distance measurement. The distance is presented in "mi" by default.
G57	Task 2	Hard to see results prices	When performing a search, the prices of the results do not appear at first glance, which complicates the choice of accommodation.
G58	Task 2	It is not possible to filter opinions	It is not possible to choose the type of opinions to display, for example only show negative opinions.
G59	Task 3	Price $0 is confusing	When selecting flights, the price is $0. It is not clear if this is because it is included in packages or if it adds that amount to the price.
G60	Task 3	"Round Trip" language is not clear	The concept of "round" is not clear, the language used is not common.
G61	Task 3	Travel and waiting times are confusing	When viewing a flight, the travel times and layover times are displayed in the same way and can be confusing.
G62	Task 3	Number of nights in package is confusing	The message "The package includes 11 nights instead of 12" is confusing, as the user was not previously presented with information about the number of nights selected.

G63	Task 3	Currency used is inconsistent on the same screen	The value of the flights is inconsistent. It is shown in CLP in the filters and in USD in the selection on the same page.
G64	Task 3	Confusing "plug" icon	When viewing a flight, an icon of a "plug" is displayed next to the name of the airline. This is confusing as no context is given.
G65	Task 3	Confusing "Building" icon	When viewing a flight, a "building" icon is displayed to indicate when the flight is "arriving". The use of this icon is inconsistent.
G66	Task 3	Popup with flight information is inconsistent	The popup displaying flight information appears on the right side of the screen, this does not match most of the website which in previous steps displayed this information in the middle or full screen.
G67	Task 3	Lack of clarity about checked baggage	It is not clear whether checked baggage is optional or not when selecting a flight.
G68	Task 3	Confusing use of asterisks	The asterisks (*) indicating that there is more information about something do not make it clear what it means.
G69	Task 3	Filters disappear	When the page is reloaded, one of the filters disappears, which is confusing.
G70	Task 3	Total price of the trip and baggage is confusing	When viewing a flight, the total price is indicated, however a price appears below for "Total Trip" and another for a piece of checked baggage, which is confusing.
G71	Task 3	Filter location is confusing	Unnecessary information in the filter section. The text "From" is not easily visible because it is not natural to use another title to the right of a filter. It seems inconsistent.
G72	Task 3	Redundant information when searching for flights	When searching for flights there is an excess of information on the screen in a very small space, which can be overwhelming.

Considering the results obtained, we can highlight that:

- 36.11% of the potential problems (26) correspond to the first task which consisted of entering the search parameters.
- 44.44% of the potential problems (32) correspond to the second task, which consists of looking for an accommodation.
- 19.44% of the potential problems (14) correspond to the third task, which consists of finding go and return flights.
- It is possible that most common application problems were found during the first 2 tasks, which could explain the low percentage found in the third task.

2.4.2 Grades assigned by evaluators ranked by criticality

Table OO presents the list of potential problems found by the evaluators, with their respective assignments of severity, frequency and criticality (see Table N), arranged in descending order of criticality.

Table OO. Grades Assigned in Group-Based Expert Walkthrough Ranked by Criticality

ID	Problem Definition	Severity	Frequency	Criticality
G27	Excess information in accommodation search	4	4	8
G40	Little clarity in accommodation prices	4	4	8
G59	Price $0 is confusing	4	4	8
G63	Currency used is inconsistent on the same screen	4	4	8
G2	Unclear and specific tab target	3	4	7
G5	Entering a new room is confusing	3	4	7
G7	Unnatural eyelash arrangement	3	4	7
G35	Inconsistent change of site language	4	3	7
G42	Results do not match search parameters	4	3	7
G57	Hard to see results prices	3	4	7
G62	Number of nights in package is confusing	3	4	7
G70	Total price of the trip and baggage is confusing	3	4	7
G72	Redundant information when searching for flights	3	4	7
G1	Origin and destination in reverse order on the main screen	3	3	6
G3	Unnecessary information about minor passengers	2	4	6
G22	Confusion when adding more than one package.	4	2	6
G23	Missing icons	3	3	6
G25	Hard to see help symbol	2	4	6
G41	Too many customization parameters	3	3	6
G46	Missing information to see compliance with search parameters	3	3	6
G49	Unintelligible text in accommodations	2	4	6
G56	It is not possible to change distance metric	3	3	6
G58	It is not possible to filter opinions	3	3	6
G60	"Round Trip" language is not clear	2	4	6
G61	Travel and waiting times are confusing	2	4	6
G67	Lack of clarity about checked baggage	3	3	6
G68	Confusing use of asterisks	3	3	6
G71	Filter location is confusing	2	4	6
G4	Entering children's information causes page expansion	2	3	5
G6	Button color is confusing	2	3	5
G9	"Baby" appears in rooms, which does not appear in the other menu	3	2	5
G17	Little clarity when cars or accommodations are added	3	2	5
G19	Room text is illegible and inconsistent	2	3	5
G20	Intrusive ads	3	2	5

G28	Unnecessary information	3	2	5
G36	Unclear how to close photos	3	2	5
G38	Unclear accommodation stars	2	3	5
G44	Multiple ways to achieve the same result	3	2	5
G48	Very Small Map	2	3	5
G66	Popup with flight information is inconsistent	3	2	5
G69	Filters disappear	3	2	5
G10	"Where will the baby sit?" must clearly indicate that it refers to the flight	2	2	4
G14	Message with strong colors	2	2	4
G16	Unclear the ability to add accommodations	3	1	4
G21	Only last room can be deleted	2	2	4
G24	Hard to see help symbol	2	2	4
G30	Non-fixed filters	2	2	4
G32	Redundant and unclear filters	3	1	4
G33	Unclear room capacity	3	1	4
G39	Repeated information in accommodation	2	2	4
G43	Prior knowledge of the user is assumed	2	2	4
G47	"VIP access" is confusing	2	2	4
G50	Insufficient zone filters	2	2	4
G54	Text "per night" not very visible when looking at prices	3	1	4
G8	Confusing button color	0	3	3
G12	Unclear calendar behavior	2	1	3
G13	Advertisement with confusing messages	2	1	3
G15	Redundant message	2	1	3
G18	Not explicit first class	2	1	3
G26	Inconsistent documentation link	2	1	3
G29	Stressful messages	2	1	3
G34	Confusing message about refunds	1	2	3
G51	Low priority property name filter	2	1	3
G52	Unclear "Select your unit" text	2	1	3
G64	Confusing "plug" icon	2	1	3
G11	Flight year is not visible when needed	1	1	2
G31	Confusing text about the amount of offers	1	1	2
G37	Unclear property rating	1	1	2
G45	Inconsistency in font size	1	1	2
G53	Room is selected by default	1	1	2
G55	Searches do not explicitly show distance to the city center	1	1	2
G65	Confusing "Building" icon	1	1	2

Considering the results obtained, we can highlight that:

- A total of 13 potential problems (18.06%) have a criticality of 7 or more, on a scale of 0-8, indicating that at least one of their severity or frequency parameters reaches the maximum value 4.

- The most critical potential problems in task 1 (G2, G5 and G7), entering the search parameters, mainly correspond to the structure of the elements on the screen. Testers note that "the purpose of the home page tabs is confusing and inconsistent" and "the order of the tabs is unnatural considering the page options". They also indicate that there are confusing elements when configuring the search, such as "the addition of new rooms is confusing given the structure of the popup containing it" and that "unnecessary information about minor passengers is requested". Finally, it is highlighted that "icons are missing to facilitate the reading of the texts on the page".
- The most critical potential problems for task 2 (G27, G40, G53, G42 and G57), selecting an accommodation, are mainly related to "excess unnecessary filters" and "excess information on the screen about the accommodation" and that most of this information is confusing, such as "it is not clear whether the final price of a stay is per person or the total". They also note that "the language of the site automatically changes to English when a property is selected" and that "the search results do not appear to match the search parameters used."
- The most critical potential problems for task 3 (G59, G63, G62, G70 and G72), the selection of the flights, mainly correspond to confusion about the values of the flights, since "when flights are selected, price indicates $0" and that "the value of the flights is shown in CLP in the filters and in USD in the selection", in addition to confusing messages such as that "the package includes 11 nights instead of 12, this is confusing as the site never displays information about the number of nights selected". In addition, the "excess of unnecessary information in very small spaces" is also highlighted, which was also identified in the accommodation search task.

In general, it is considered that despite the fact that the method is more time-consuming at the beginning (with a single session lasting about 3 hours), the total time invested to obtain the final results is much less, as a second session for assigning severity and frequency is not needed like in a heuristic evaluation.

2.5 Perception Questionnaire

After conducting the inspection methods property checklist, perspective-based inspection and group-based expert walkthrough, the evaluators answered a perception questionnaire to know their perception after interacting with the website. The results show that:

- The participants have heterogeneous opinions about how oriented the user feels when interacting with the website. A total of 4 participants (36.36%) state that users feel little oriented, and on the contrary, 4 participants (36.36%) state that users feel oriented when interacting with the website.
- 45.45% of the evaluators (5 evaluators) think that the interaction with the website is difficult. In addition, 4 evaluators (36.36%) believe that interacting with the website is easy.
- A total of 4 evaluators (36.36%) have a neutral opinion and 3 evaluators (27.27%) state that the interactions they have had with the website are ineffective when trying to achieve their goals.
- 45.45% of the evaluators (5 evaluators) believe that their level of satisfaction with the system was unsatisfactory.

- A total of 8 evaluators (72.72%) would not recommend the expedia website to book accommodation and flights.
- 63.63% of the evaluators (7 evaluators) believe that the application is not attractive for users with ASD.
- A total of 7 evaluators (63.63%) believe that the website does not create an environment of trust for the users with ASD.
- 63.63% of the evaluators (7 evaluators) mention that the elements of the application are not ordered, structured in a coherent and consistent manner throughout the interaction.
- A total of 8 evaluators (72.72%) believe that the website does not take into account the needs of users with ASD.
- 45.45% of the evaluators (5 evaluators) have a neutral opinion on whether the application elements (texts, icons, processes, among others), as well as the interactions with these elements, are familiar and similar to those that can be found in real life.
- A total of 8 reviewers (72.72%) mention that the website is not customizable.
- 81.81% of the evaluators (9 evaluators) state that the website design does not take into account the sensory characteristics of the user with ASD (vision, hearing and touch).
- A total of 8 evaluators (70%) believe that the website does not hold the attention of users with ASD.
- 45.45% of the evaluators (5 evaluators) think that the website does not manage time properly.
- A total of 9 evaluators (81.81%) believe that the website does not avoid frustration for users with ASD during their interaction.

The evaluators highlight the color palette used, the variety of search options, information, and flight and accommodation results. On the other hand, the evaluators emphasize the lack of personalization, the overload of unclear and inconsistent information and the lack of detail about the prices throughout the process.

3 User Tests

To evaluate the expedia.com website with users with ASD, we conducted a field observation with 4 participants with ASD level 1 [1], through video calls. A session was scheduled on a day and time available to each participant.

3.1 Field Observation

For the application of the evaluation, the following steps were carried out:

1. The evaluation participants were contacted before the day of application of the evaluation method.
2. The users were informed that the session will be recorded. Participants were asked to turn off their cameras to maintain their anonymity.
3. Each participant was asked to read and give their consent to make the recordings.

4. Users were asked to freely explore the expedia.com website, with the aim of searching for an ideal holiday, taking into account accommodation and flight (round trip).
5. Finally, the participants were asked to answer a perception questionnaire about the expedia website.

In addition, it is important to mention that there was an evaluator who accompanied the participants through the application of the evaluation, without interrupting the process. Only if the user requested it, the evaluator provided support.

The observations collected and results obtained by each participant are presented below.

3.1.1 First Participant

The results obtained with the first participant are:

- The participant believes that selecting a region at the top of the website is the destination country of their search.
- It is not known where to look. The user explores all the search options presented by the user until he settles on the first option (accommodation).
- Confusion due to an error not specified by the site when changing the region. The user changes to the Mexican region, so the values of the accommodation are detailed in Mexican pesos.
- Frustration when not being able to change the currency used by the site.
- When searching for destination locations on the site, it only recommends locations from the participant's country, so the user believes they have made a mistake and asks the site for the place of origin.
- Confusion in the tab of the accommodation offered, as the results of the search carried out cannot be appreciated at first glance due to the amount of information.
- Annoyance not to find a filter that helps filter the accommodation only by apartments.
- When an accommodation is selected, the website opens a new tab with its details. The user does not know which tab to continue interaction with.
- After seeing the photos of a particular accommodation, the user does not know how to go back to continue the reservation.
- The information previously entered on the website, such as the start and end days of the trip, is not perceived by the user at first glance, so they constantly look for the information in the tabs previously opened by the website.
- The dates of the flights are not observed by the user.
- It is not understood how to book flights on the website.
- Confusion when selecting the return flight as the user does not see the change on the website of the return flight tabs. It is believed that the user made a mistake when selecting the outbound flight and the website asks for this information again.
- At the moment of entering the personal data, before the payment, it is not known at first glance where you can communicate.

In addition, it is highlighted that the participant's attention was distracted by the images of the accommodation and the general perception of the website is very good, because the user found an accommodation with characteristics that it would like to have for her holidays.

The user spent around 48 minutes searching for accommodation and flights for their ideal holiday.

3.1.2 Second Participant

The results obtained with the second participant are:

- Annoyance when you see the message "Welcome to Expedia.com. Continue to the Chile website at Expedia.com", as the website still shows the information in English and not Spanish.
- The user has no problem finding the search section in the flight option.
- Annoyance at the font size of the site. There is no way to adjust this aspect on the website, so the participant zoomed in on the browser.
- Annoyance when changing the currency.
- The user performs the search on the website, as soon as it explores the accommodation offered, it tries again to change the currency. The website allows it to change the currency, but the search performed is removed and the user is redirected to the main page.
- The user expresses discomfort saying "why is the x on the left?", when viewing the details of the flights. The website only allows you to close the flight details by pressing the "x".
- When the number of passengers at the top of the search is changed, all previously selected filters are removed.
- If you select an airline in the upper part of the search, exclusive flights with that airline are displayed. Not so with the filters available in the lower left section.
- Annoyance with the details of the flights, as prices can only be compared on some flights in relation to the "category" of the seat, for example: economy, premium economy, business class.
- The user states that the website needs to highlight important flight information, for example when connecting flights have different "categories" of seats, despite the fact that a "category" was previously selected.
- Annoyance because the luggage capacity is in pounds.
- Confusion with the flights where it is mentioned that the value is "+ CLP 0".
- The participant assumes that the second information provided by the flight, "16h 2min in Toronto (YYZ)", refers to the layover times.
- Confusion with the message "Savings are based on all flight and hotel package bookings on Expedia between January and December 2019 (...)", as that date has already passed.
- Confusion with the message "Book a car with your flight and save up to CLP 267", as he believes that, being very literal, it means that a car will cost him this price.

In addition, it is highlighted that the participant expressed anxiety throughout the process of interacting with the website, as the loading bar does not have a continuous animation. The user spent around 35 minutes searching for accommodation and flights for their ideal holiday.

3.1.3 Third Participant

The results obtained with the third participant are:

- Annoyance when seeing the message "Welcome to Expedia.com. Continue to the Chile website at Expedia.com", as the website still displays the information in English and not Spanish. All participant interaction with the website is done in English.
- The search is done with the accommodation option. There is no interaction with the other options offered by the website.
- The participant hoped that the website would provide additional information when “Add a car” was selected.
- The user does not know whether the value of the accommodation shown is per day or not.
- Annoyance when you want to order the prices of the accommodation offered in descending order. The website only offers the option to sort the accommodation by price category, but it is not known whether it is sorted in ascending or descending order.
- The user feels uncertain when choosing a hosting, as he does not know whether to continue in the page where the hosting was selected or in the new page opened by the website. This is why the user tried twice to book the desired accommodation.
- The user points out that when searching for flights on the site, it does allow to sort the search results by price in ascending or descending order.
- Confusion when seeing that the outbound flight is +US$0.
- Uncertainty about when the website loads the information or not.
- The user has selected the option to rent a vehicle. Annoyance when wanting to filter the results offered by the mechanical vehicle website. The user looks for this option in the "Specifications" filter category, which offers the options "Automatic" and "Unlimited mileage".
- Annoyance by not seeing filters such as the brand or type of transmission of the vehicle and if by rental car company.
- Confusion when choosing a vehicle as the site offers two vehicles with the same descriptions. It is assumed that it is completely different, but they do not know what the difference is.
- Annoyance that the site is not standard and consistent between its tabs.

The participant highlights how monotonous the site is. It mentions that "the search is not intuitive" as it would expect the steps to follow to be flight, accommodation and vehicle, not accommodation, flight and vehicle. In addition, it is mentioned that "the website is useful, but the way the information is presented is not useful". The user spent approximately 29 minutes searching for accommodation and flights for their ideal holiday.

3.1.4 Fourth Participant

The results achieved with the fourth participant are:

- At the beginning, the user does not realize how to change the language of the website.
- The search for holidays is done with the accommodation option.
- Frustration because the website does not allow you to change the currency, so the user evaluates the option of using an external page to make the change.

- As soon as the user interacts with the accommodation offers, the language of the website changes, which changes the language and the prices of the accommodation are eliminated.
- Each time the user selects a new filter, the site scrolls the screen to the top of the tab. The user states that this situation stresses him.
- Annoyance at the moment that you cannot order the accommodation by price in descending order.
- The participant performs two separate searches for multi-stop flights. The site does not offer the option of multiple stopovers with accommodation.
- The user does not know whether the message "The price of your trip has dropped from CLP 440,771,734 to CLP 467,033 is an error on the website or not. Book now to secure this price." It is believed that the price has increased and not decreased.

The participant spent approximately 25 minutes searching for accommodation and flights for their ideal holiday.

3.2 Perception Questionnaire

After searching for the ideal holiday on the expedia website, participants were asked to answer a perception questionnaire, in order to find out their perception after interacting with the website. The results show that:

- A total of 3 participants (75%) felt oriented during their interaction with the website.
- 75% of the participants (3 participants) mention that it was easy to interact with the website.
- 100% of participants (4 participants) stated that their interactions with the website were effective in achieving their goals.
- All the participants (4) mentioned that they felt satisfied after interacting with the website.
- 50% of the participants (2 participants) would recommend using the expedia website to search for flights, accommodation, among others. One participant would not recommend it and another user has a neutral opinion.
- A total of 3 participants (75%) believe that the website provides attractive content.
- 75% of the participants (3 participants) state that the website generates a reliable environment to interact.
- A total of 3 participants (75%) mention that the elements of the website are presented in an orderly, structured, coherent way and are consistent throughout the interaction.
- 75% of the participants (3 participants) believe that the website elements and interactions are familiar and similar to what can be found in real life.
- Participants have mixed opinions about how customizable the site is. 50% of the participants agree and the other 50% disagree about how customizable the website is.
- The participants have heterogeneous opinions about whether the visual elements or interactions (clicks or keyboard) made them uncomfortable. 50% of respondents disagreed and the other 50% agreed about how uncomfortable they were with the visuals or interactions on the website.

- 75% of the participants (3 participants) stated that they were frustrated during the interaction with the website.
- Participants emphasize that they liked the website: (1) ease of use, (2) diversity of options, (3) visually attractive, elegant and minimalistic, and (4) diversity of offers.
- On the other hand, they mention that they did not like the Expedia application: (1) that it is not possible to change the currency and language easily, (2) elimination of searches made when the language or region being changed, (3) animation of the loading bar, (4) lack of consistency, (5) lack of price details and (6) that when a filter is selected, the screen is moved to the top of the site.

4 Grouping of Potential Problems

To evaluate the UX of the expedia website, the inspection methods, perspective-based inspection and group-based expert walkthrough were implemented, in which a total of 34 and 72 potential problems were identified, respectively.

In addition, the consolidated list of potential problems of the heuristic evaluation performed by the creator of the set of heuristics to evaluate the UX for systems used by people with ASD, Ignacio Castro, was considered. In this heuristic evaluation, a total of 39 potential problems were identified, with the support of 7 evaluators.

Considering all 145 potential problems identified in the three evaluation methods, perspective-based inspection, group-based expert walkthrough and heuristic evaluation, they were consolidated into a single list of potential problems. For each potential problem, an ID, definition, explanation, and evaluations of frequency, severity, and criticality were identified. After analyzing all the potential problems, a total of 10 repeated potential problems were identified. For each of the potential repeat problems, a new ID has been assigned, the source IDs are shown, and a single definition and explanation has been generated. Table PP presents the redefined repeated potential problems from the consolidated potential problems list.

Table PP. Repeated Potential Problems Consolidated Definitions

Origin ID	New ID	Consolidated Problem Definition	Consolidated Comments and Explanation
G27 y C5	PR1	Excess of information in accommodations	The accommodation page contains too much information and images that can be distracting.
G59, C9 y J10	PR2	Price +$0 is confusing	When selecting flights, the price is $0. It is not clear if this is because it is included in packages or if it adds that amount to the price.
G63, C11 y H36	PR3	Currency used is inconsistent	The value of flights and accommodation is inconsistent. The website constantly changes the currency used, even in the same tab different types of currency are used.
G35 y H22	PR4	Inconsistency in the language used	The website automatically changes the language used, for example when accommodation is selected, and in some

			sections the information is presented in a language other than the one selected.
G42 y I4	PR5	Results do not match search parameters	When searching for an accommodation, many of the search results presented do not necessarily match the selected search parameters.
G72 y H23	PR6	Too much information in flights	When searching for flights there is an excess of information on the screen in a very small space, which can be overwhelming.
G28 y H34	PR7	Irrelevant information in accommodations	The accommodation page shows information regarding flights, which we consider irrelevant as we are focused on the search for accommodation.
G14, I1 y J1	PR8	Message with strong colors	While defining the people who will be in each room, when the button with a "+" for the "Kids" or "Babies" section is pressed, a red box (strong color) suddenly appears asking them to add the ages of the children. The message is intrusive and can distract users with ASD.
C10, I3 y H5	PR9	The font size is not adequate	The system uses a very small font size, which makes it difficult to read. What is important in the information is not highlighted.
C14, I2 y H16	PR10	Slow response time	The website takes a long time to load the information and does not provide feedback about the loading process or error that occurred.

After consolidating the potential repeated problems, we can mention that: (1) a total of 10 potential problems were created with new definitions and explanations, based on the potential repeated problems, (2) for the group-based expert walkthrough evaluation, a total of 64 potential unique problems were identified, (3) for the perspective-based inspection evaluation a total of 28 potential unique problems were identified and (4) for the heuristic evaluation a total of 33 potential unique problems were identified. Considering these results, we can conclude that a total of 135 unique potential problems were identified on the expedia.com website, through the 3 inspection methods (perspective-based inspection, group-based expert walkthrough, and heuristic evaluation).

Table QQ presents the new IDs and definitions of the potential problems created based on the repeated problems, with the averages and standard deviations for severity (S), frequency (F) and critical points (C).

Table QQ. Repeated Potential Problems Consolidated Values

		Average			**Standard Deviation**		
New ID	**Consolidated Problem Definition**	**S**	**F**	**C**	**S**	**F**	**C**
PR1	Excess of information in accommodations	4	3.5	7.5	0	0.5	0.5

PR2	Price +$0 is confusing	3.67	3	6.67	0.47	0.82	1.25
PR3	Currency used is inconsistent	2.78	2.89	5.67	0.92	0.87	1.56
PR4	Inconsistency in the language used	2.75	2.5	5.25	0.83	0.71	1.3
PR5	Results do not match search parameters	3,00	3.5	6.5	1	0.5	0.5
PR6	Too much information in flights	2.25	3.13	5.38	0.43	0.78	0.86
PR7	Irrelevant information in accommodations	2.25	2.38	4.63	0.83	0.86	1.32
PR8	Message with strong colors	2	2.33	4.33	0.82	1.25	0.47
PR9	The font size is not adequate	2.22	1.78	4	1.13	1.4	1.63
PR10	Slow response time	2	2.67	4.67	0.47	0.67	0.67

Considering the results obtained in the averages and standard deviations of the potential repeated problems, we can state that: (1) A total of 5 potential problems have a standard deviation greater than 1.25, which implies that the evaluators do not do not agree in their opinions, (2) the potential problems G63 and C11, identified in the group-based expert walkthrough and perspective-based inspection, were considered the most critical (8 criticality), but, when averaged with the potential problem H36 , identified in the heuristic evaluation, this decreased in criticality to 5.67, (3) the potential problem G35 with a criticality of 7, was considered a more critical potential problem of the group-based expert walkthrough method, but because it was averaged with the potential problem H22, it has reduced its criticality to 5.25, and (4) it can be observed that 9 of the 10 potential repeated problems have an average frequency greater than 2.33 on a scale of 0-4, which we believe was a relevant factor when it comes to their detection in multiple evaluation methods.

5 Results and Recommendations

After applying the methodology to evaluate the user experience [12] on the expedia.com website [182], we can conclude that:

- It is important to improve the aspects related to the 9 categories described in the property checklist (see appendix F) on the website, since the results do not show positive results. Efforts should be focused on the adaptive and attention retention categories. Allowing customization of aspects such as font size, language, and currency used on the website can help improve user perception of customization. Not overloading the site with information, not taking unexpected actions, for example opening new tabs without warning, and providing quick answers with timely feedback will help keep users' attention.
- The 34 potential problems found by the evaluators in the perspective-based inspection evaluation method, among the three proposed perspectives, must be addressed by prioritizing the most critical potential problems. Considering the most critical potential problems for each perspective, we recommend that:

- Based on the most critical potential problems, identified from the perspective of a novice user with ASD (C11, C2, C5 and C9), we can conclude that it is important to provide consistency throughout the interaction, not to overload information, and give feedback in a timely and specific manner.
- Considering the most critical potential problems, identified from the perspective of an expert user with ASD (I2 and I4), we can conclude that it is important not to have delays and deliver results according to the search performed.
- Through the most critical potential problems, identified from the perspective of a user error handling with ASD (J4, J7 and J10), we can conclude that it is important to provide better clarity between the options provided by the website (including the usage icons) and provide explicit details of the information delivered to users.

- In addition, the 72 potential problems found by the evaluators in the group-based expert walkthrough evaluation method must be addressed, with the priority of the most critical potential problems. For the most critical potential problems, we offer the following recommendations:
  - G27 "Overload of information in accommodations": The overload of information when the details of the accommodations are presented must be reduced. It is recommended to remove the information provided by each redundant host and redistribute the information.
  - G40 "Lack of clarity in accommodation prices": It is proposed to provide a detail of the prices and charges of the chosen accommodation, including whether this value is per night, per person, etc.
  - G59 "Price $ 0 is confusing": The values charged by the website should be specified in more detail and give feedback to the user in the case of generating discounts for packages or similar.
  - G63 "Currency used is inconsistent on the same screen": Consistency of the currency used throughout the site must be provided.
- The results obtained with the user test confirm the importance of solving the potential problems identified in the inspection methods. Potential issues such as (1) the need for customization elements, such as seamlessly adjusting the language, currency and font size, (2) consistency of the currency and language used throughout the website, (3) confusion with the message "+CLP 0" and (4) the need to provide clear and timely feedback on the prices and charges provided by the website are potential problems confirmed by the results obtained in the field observation. In addition, it stands out from this evaluation that (1) the sequence of steps should be logical and intuitive, (2) provide harmonious animations that do not generate anxiety and (3) do not suddenly interrupt the user interaction when a filter is selected.

APPENDIX K

Guide questions by perspective-based inspection.

Table RR. Guide Questions for Novice User with ASD

Task: 1. Entering travel parameters (dates, passengers, places, etc.)
1. Is the section for entering trip parameters clearly identified? 2. Is the section to enter the parameters of the trip attractive to the user? 3. Does the user receive adequate feedback when entering ride parameters? 4. When the ride parameters are entered, is the behavior of the elements on the screen predictable? 5. Does the section for entering trip parameters have a clear, simple and consistent structure? 6. Is the purpose of the elements on the screen clear and explicit? 7. Shouldn't the user remember the selected items? 8. Do the on-screen instructions have adequate and concise language? 9. Are the elements and interactions presented known to elements known/learned by the user outside the system? 10. Is there some customization in the choice of trip parameters? 11. Is the selection of parameters designed taking into account the sensory characteristics of users with ASD (sight, hearing and touch)? 12. Does the parameter selection contain distracting elements for the user? 13. Isn't it frustrating to enter the trip parameters?
Task: 2. Find accommodation
1. Is the accommodation offered by the website clearly identified? 2. Is the presentation of the accommodation offered attractive to the user? 3. Does the user receive sufficient feedback on each accommodation? 4. Is the behavior of the elements on the screen predictable when searching for and choosing an accommodation? 5. Is the search and selection of accommodation clear, simple and consistent? 6. Is the purpose of the elements on the screen clear and explicit? 7. Shouldn't the user remember the selected items? 8. Do the on-screen instructions have adequate and concise language? 9. Are the elements and interactions presented known to elements known/learned by the user outside the system? 10. Is there some personalization in the search and selection of accommodation? 11. Is the search and selection of accommodation designed taking into account the sensory characteristics of users with ASD (sight, hearing and touch)? 12. Does the search and selection of accommodation contain distracting elements for the user? 13. Isn't the search and choice of accommodation frustrating?
Task: 3. Find outgoing and return flight
1. Is the information of the flights offered by the website clearly identified? 2. Is the presentation of the flights offered attractive to the user? 3. Does the user receive sufficient feedback on each flight? 4. When searching and selecting a flight, is the behavior of the elements on the screen predictable? 5. Is the search and selection of flights clear, simple and consistent? 6. Is the purpose of the elements on the screen clear and explicit? 7. Shouldn't the user remember the selected items?

8. Do the on-screen instructions have adequate and concise language? 9. Are the elements and interactions presented known to elements known/learned by the user outside the system? 10. Is there some personalization in the search and selection of flights? 11. Is the flight search and selection designed taking into account the sensory characteristics of users with ASD (sight, hearing and touch)? 12. Do you consider that the search and selection of flights does not contain distracting elements for the user? 13. Isn't the search and selection of flights frustrating?

Table SS. Guide Questions for Expert User with ASD

Task: 1. Entering travel parameters (dates, passengers, places, etc.)
1. Is the section to enter the parameters of the trip quickly identified? 2. Are the most used options/items easy to identify at first glance? 3. Does the user receive adequate feedback when entering trip parameters? 4. When the trip parameters are entered, is the behavior of the elements on the screen predictable? 5. Does the section for entering trip parameters have a clear, simple and consistent structure? 6. Shouldn't the user remember the selected items? 7. Does the site avoid displaying redundant information? 8. Is the selection of parameters designed taking into account the sensory characteristics of users with ASD (sight, hearing and touch)? 9. Does the website perform calculations automatically for ease of use? 10. Are there default values? 11. Are there shortcuts for actions (such as using the keyboard)? 12. Are unproductive actions (mouse movement, switching from mouse to keyboard, or eye movement across the screen) minimized? 13. Are stressful actions minimized? 14. Are the response times of the website adequate?
Task: 2. Find accommodation
1. Do you quickly identify the accommodation offers offered by the website? 2. Is the most relevant information about the accommodation easy to identify at first glance? 3. Does the user receive sufficient feedback when searching for an accommodation? 4. Is the behavior of the elements on the screen predictable when searching for and choosing an accommodation? 5. Does the search and selection of accommodation have a clear, simple and consistent structure? 6. Shouldn't the user remember the selected items? 7. Does the site avoid displaying redundant information? 8. Is the search and selection of accommodation designed taking into account the sensory characteristics of users with ASD (sight, hearing and touch)? 9. Does the website perform calculations automatically for ease of use? 10. Are there default values? 11. Are there shortcuts for actions (such as using the keyboard)? 12. Are unproductive actions (mouse movement, switching from mouse to keyboard, or eye movement across the screen) minimized? 13. Are stressful actions minimized? 14. Are the response times of the website adequate?

Task: 3. Find outgoing and return flight
1. Do you quickly identify the flight deals offered by the website? 2. Is the most relevant flight information easy to identify at first glance? 3. Does the user receive sufficient feedback when searching for flights? 4. Is the behavior of the elements on the screen predictable when searching and selecting flights? 5. Does the search and selection of flights have a clear, simple and consistent structure? 6. Shouldn't the user remember the selected items? 7. Does the site avoid displaying redundant information? 8. Do you consider that the search for and selection of flights is designed taking into account the sensory characteristics of users with ASD (sight, hearing and touch)? 9. Does the website perform calculations automatically for ease of use? 10. Are there default values? 11. Are there shortcuts for actions (such as using the keyboard)? 12. Are unproductive actions (mouse movement, switching from mouse to keyboard, or eye movement across the screen) minimized? 13. Are stressful actions minimized? 14. Are the response times of the website adequate?

Table TT. Guide Questions for Error Handling User with ASD

Task: 1. Entering travel parameters (dates, passengers, places, etc.)
1. Does the site prevent the user from skipping a trip parameter? 2. Is it easy to distinguish a mandatory or optional trip parameter? 3. Is it impossible to accidentally execute unwanted options? 4. Is the relevant information easily visible and not hidden behind other elements and/or options? 5. When the trip parameters are entered, is the behavior of the elements on the screen predictable? 6. Is it difficult to cause errors by performing an action whose result is contrary to the user's expectations? 7. Is it possible to perform actions in the wrong way (for example: typing before activating a text field, entering data in the wrong place, navigating to the wrong place, etc.)? 8. Does the section for entering trip parameters do everything possible to avoid errors? 9. In the event of an error, will the user be immediately aware of the error and understand the nature of the error from the UI response? 10. Does the user interface minimize the side effects that could cause the error? 11. In the event of an error, does the user interface provide guidance for the user to recover from the error, including guidance on reversing side effects?
Task: 2. Find accommodation
1. Does the website prevent the user from omitting information when searching for and selecting an accommodation? 2. Is it easy to distinguish the accommodation information that is mandatory or optional? 3. Is it impossible to accidentally execute unwanted options? 4. Is the relevant information easily visible and not hidden behind other elements and/or options? 5. Is the behavior of the elements on the screen predictable when searching for and choosing an accommodation?

6. Is it easy to cause errors by performing an action whose result is contrary to the user's expectations? 7. Is it possible to perform actions in the wrong way (for example: typing before activating a text field, entering data in the wrong place, navigating to the wrong place, etc.)? 8. Does the department for searching and choosing accommodation do everything possible to avoid errors? 9. In the event of an error, will the user be immediately aware of the error and understand the nature of the error from the UI response? 10. Does the user interface minimize the side effects that could cause the error? 11. In the event of an error, does the user interface provide guidance for the user to recover from the error, including guidance on reversing side effects?
Task: 3. Find outgoing and return flight
1. Does the website prevent the user from omitting information when searching and selecting flights? 2. Is it easy to distinguish the flight information that is mandatory or optional? 3. Is it impossible to accidentally execute unwanted options? 4. Is the relevant information easily visible and not hidden behind other elements and/or options? 5. Is the behavior of the elements on the screen predictable when searching and selecting flights? 6. Is it easy to cause errors by performing an action whose result is contrary to the user's expectations? 7. Is it possible to perform actions in the wrong way (for example: typing before activating a text field, entering data in the wrong place, navigating to the wrong place, etc.)? 8. Does the flight search and selection section do everything possible to avoid errors? 9. In the event of an error, will the user be immediately aware of the error and understand the nature of the error from the UI response? 10. Does the user interface minimize the side effects that could cause the error? 11. In the event of an error, does the user interface provide guidance for the user to recover from the error, including guidance on reversing side effects?

APPENDIX L

sensors

MDPI

Review

The Impact of Technology on People with Autism Spectrum Disorder: A Systematic Literature Review

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Abstract: People with autism spectrum disorder (ASD) tend to enjoy themselves and be engaged when interacting with computers, as these interactions occur in a safe and trustworthy environment. In this paper, we present a systematic literature review on the state of the research on the use of technology to teach people with ASD. We reviewed 94 studies that show how the use of technology in educational contexts helps people with ASD develop several skills, how these approaches consider aspects of user experience, usability and accessibility, and how game elements are used to enrich learning environments. This systematic literature review shows that the development and evaluation of systems and applications for users with ASD is very promising. The use of technological advancements such as virtual agents, artificial intelligence, virtual reality, and augmented reality undoubtedly provides a comfortable environment that promotes constant learning for people with ASD.

Keywords: user experience; accessibility; autism spectrum disorder; game-based learning; systematic literature review

1. Introduction

Currently, autism spectrum disorder (ASD) affects a significant number of people who have difficulties with communication and socialization, which results in complexities for their learning. Studies have examined the use of technology and computer-based interventions to teach people with ASD language and social skills [1]. Specifically, students on the autism spectrum enjoy playing games, which provides a safe environment [2]. Thus, we reviewed the existing literature about the relationship between technology, games, user experience, accessibility, and the education and skill development of people with ASD. This article is organized as follows: Section 2 presents the theoretical background, Section 3 describes the research methodology, Section 4 analyzes the results obtained, and finally, Section 5 highlights the conclusions and recommendations for future work.

2. Theoretical Background

2.1. Autism Spectrum Disorder

Asperger's syndrome was defined in 1944 by Hans Asperger [3]. The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [4] defines autism spectrum disorder (ASD) as a condition characterized by deficits in two core domains: (1) social communication and social interaction and (2) restricted repetitive patterns of behavior, interests, and activities. Since 2013, the DSM-5 has recognized Asperger's disorder, childhood disintegrative disorder, Rett's disorder, and several other related disorders, as part of ASD. However, many studies still use the Asperger's syndrome and ASD almost interchangeably.

In a study carried out by the National Institute of Health (NIH) of the USA [5] published in June 2018, it was estimated that 2.41% of children in the United States of America have an autism spectrum disorder. This shows an increase of 0.94% compared to 2010.

2.2. User Experience

The international standard on ergonomics of human system interaction, ISO 9241-210 [6], defines user experience as "user's perceptions and responses that result from the use and/or anticipated use of a system, product or service". In other words, the user experience is the degree of "satisfaction" that the end user has with the system or service after using it, that is based on each of the interactions that he or she has.

According to Peter Morville [7], user experience is meaningful and valuable when a product, service or system is useful (that is, its content is original and satisfies a need), usable (the product is easy to use), desirable (the image, identity, brand, and other design elements produce positive emotions towards the product), locatable (the content is accessible to people with disabilities), credible (users have confidence in the product), and valuable (an added value is generated from the product).

2.3. Accessibility

The international standard on ergonomics of human system interaction, ISO 9241-171 [8] defines accessibility as the "extent to which products, systems, services, environments, and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use". In other words, accessibility is the condition that environments, services, processes, and objects (everything that involves an interaction) must meet, which must be understandable and usable by the broadest range of people, regardless of their capabilities.

2.4. Game-Based Learning

Games that use technology are widely used to teach people conceptual knowledge and skills. There are different implementations of such games, such as serious games, gamification, and e-learning.

2.4.1. Serious Games

Serious games are games whose main objective is not fun or entertainment but the learning or practice of skills. In 1970, Clark Abt [9] defined this concept as follows in his book called "Serious Games"—"games that have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement. This does not mean that serious games are not, or should not be, entertaining".

2.4.2. Gamification

The concept of gamification was developed in 2003, and its use became widespread in 2010 through the work of multiple professionals. Gamification is formally defined as "the use of game elements and game design techniques in nongame contexts" [10]. When we talk about gamification, we tend to interpret it as a methodology where the purpose is to provide rewards to users to inspire personal and collective commitment, but this interpretation is very far from reality. Many authors maintain that the success of a gamified system or process lies in good design and adequate feedback, among many other factors. Other authors have supported this argument: for example, Kapp [2] stated, "Do not think of gamification as only the use of badges, rewards, and points. Instead, think of the engaging elements of why people play games—it is not just for the points—its [sic] for the sense of engagement, immediate feedback, and the success of striving against a challenge and overcoming it".

2.4.3. E-Learning

The term “e-Learning” comes from the abbreviation of “electronic learning”. Khan [11] defined e-Learning as "a hypermedia instructional program that uses the attributes and resources of the Internet to create meaningful learning environments." That is, e-Learning refers to online teaching and learning through the Internet and technology.

2.5. Game Elements

Game elements are the components that make up a game to create an attractive experience for players. Werbach [10] described 25 such game elements. For the purpose of our study, we identify the relevant game elements are as follows:

- Narrative: Telling of a coherent story.
- Progression: Player growth and development.
- Challenges: Tasks that require an effort to perform.
- Competition: Players or groups that win or lose.
- Rewards: Benefits granted after a certain action.
- Feedback: Information about how the player is performing.
- Avatars: Visual representation of a player character.
- Collections: Set of items that can be accumulated.
- Levels: Steps defined in the progression of a player.
- Leaderboard: Visual representation of the player’s progression with respect to others.
- Points: Numerical representation of the player’s progression.
- Achievements: Accomplishment of defined objectives.
- Teams: Group of players who work together to achieve a common goal.

3. Research Methodology

This systematic literature review was carried out following the process proposed by Kitchenham [12]. Kitchenham outlined three fundamental phases for conducting a review of the literature: (1) planning the review, which includes creating the research questions and reviewing the protocol; (2) conducting the review, which includes the review, the selection and quality of studies, data extraction and data synthesis; and (3) publicizing the results after the review. Next, we detail the process followed for this document.

3.1. Research Questions

To cover every topic of interest in this systematic literature review, we formulated three research questions. These questions consider relevant and general aspects important for comprehending the concepts that we think are important for this study. These questions can be seen in Table 1.

Table 1. Research questions for the systematic literature review.

ID	Research Question (RQ)
RQ1	In what way does the use of technology contribute to the education of people with autism spectrum disorder?
RQ2	Which user experience and accessibility elements/methods are considered when analyzing the impact of technology on people with autism spectrum disorder?
RQ3	Which game elements are considered when using gamification or serious games in the education of people with autism spectrum disorder?

3.2. Data Sources and Search Strategies

To conduct this systematic literature review, we searched for scientific papers on five databases: IEEE Xplore Digital Library, ACM Digital Library, Science Direct, Scopus, and Web of Science. For

these sources, we considered only documents that were relevant in computer-related categories, such as technology, engineering and computer science, excluding categories related to medicine or chemistry. Additionally, we selected articles published during the last 10 years, between January 2009 and June 2019.

3.3. Article Selection

Once we chose the databases to search, we determined the specific search strings to find articles to answer the research questions and defined the exclusion and inclusion criteria to refine and filter the articles found.

3.3.1. Search Strings

We formulated the search strings based on the relevant topics to our systematic literature review. We determined a set of specific keywords to use in our queries, i.e., "Autism Spectrum Disorder", "Accessibility", "User Experience", "Gamification", "Serious Games", and "Game Elements" that would be useful to answer our research questions.

These strings were focused on finding studies that analyzed or experimented with the use of games with people with ASD, considering aspects such as the user experience, accessibility, and game elements. In Table 2, we present the specific search strings that were used in the selected databases.

Table 2. Search strings.

ID	Search Strings
SS1	("Autism spectrum disorders" OR ASD OR Autism) AND (Accessibility OR "User experience") AND ("game elements" OR gamification OR "Serious game" OR "game-based learning")
SS2	("Autism spectrum disorders" OR ASD OR Autism) AND (Accessibility OR "User experience")
SS3	("Autism spectrum disorders" OR ASD OR Autism) AND ("game elements" OR gamification OR "Serious game" OR "game-based learning")

3.3.2. Study Selection Criteria

To answer the research questions based on the selected articles and develop a general knowledge of the concepts that we were working with, we included the conditions listed in Table 3.

Table 3. Inclusion criteria.

ID	Inclusion Criteria
IN1	Studies published over the last 10 years, between January 2009 and June 2019.
IN2	Journal articles and conference papers.
IN3	Studies with a focus on autism spectrum disorder.
IN4	Studies related to the usage of technology.
IN5	Studies performed in an educative context or focused on teaching.

The types of papers presented in Table 4 were excluded.

Table 4. Exclusion criteria.

ID	Exclusion Criteria
EX1	Studies with an exclusive medical focus or a focus on the diagnosis of autism spectrum disorder.
EX2	Studies that do not directly aim to help people with autism spectrum disorder but rather the people who work with them.
EX3	Studies that consider user experience and accessibility in contexts that do not involve the use of technology.

3.4. Document Selection

Applying the selection criteria, we gathered a total of 94 articles. Figure 1 shows the general process flow of the search and study selection for this review, detailing the inclusion and exclusion criteria applied in each step.

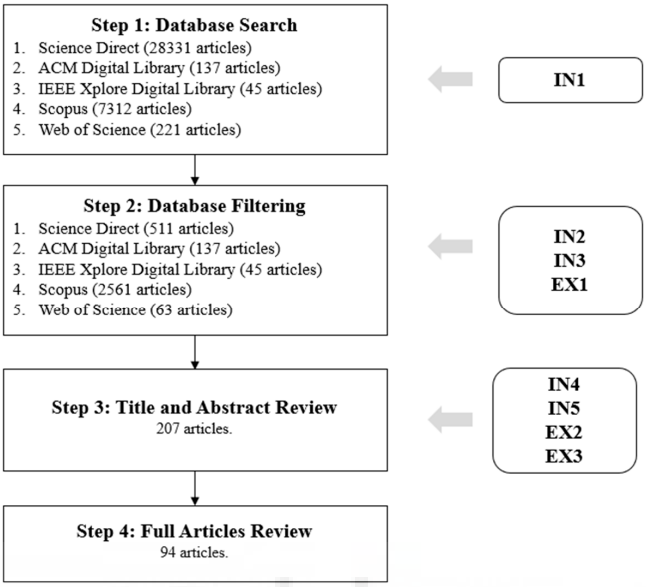

Figure 1. Flow chart with the results of the article selection process.

3.5. Data Synthesis

After the search, we extracted the information from each of the 94 studies, summarizing and tabulating the information based on different metrics, such as the year published, document type and paper category. In the following steps, we detail each of the metrics.

3.5.1. Year of Publication

As detailed above in the inclusion criteria section, we considered studies published during the last 10 years, between 2009 and 2019. As shown in Figure 2, we plotted the number of studies that were found that were published between 2009 and 2018, and we observed an increase in publication on this topic over this period. The studies found in 2019 are not presented in this plot because it would have been misleading to show incomplete data, as this review was finished in June 2019. Seventeen studies published in 2019 were found (almost equal to the number of publications in 2018), which led us to believe that this number will undoubtedly increase significantly during the remaining months of 2019.

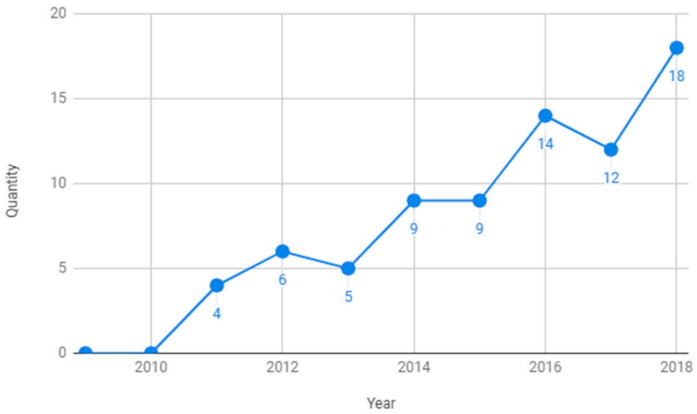

Figure 2. Year of publication.

3.5.2. Document Type

We analyzed the origin of the studies reviewed and determined whether they were conference proceedings or had been submitted to a scientific journal. Figure 3 shows a relative balance between the number of papers that were published as conference proceedings and in journals.

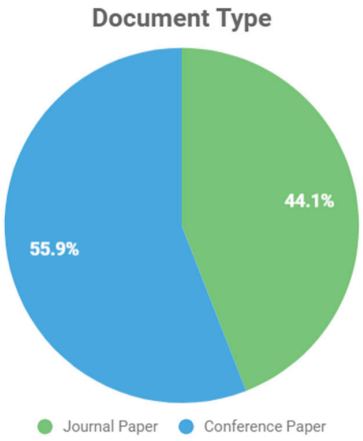

Figure 3. Document Type.

3.5.3. Document Categories

The studies were categorized as follows:

- Review: An updated summary of a particular topic is provided.
- Case Study: A solution is given to a presented problem based on a tool, methodology, etc.
- Empirical Data: A context or situation is analyzed based on historical data.

Figure 4 shows that 74.5% of the studies analyzed were case studies. It is believed that this is because the researchers were focused mainly on conducting investigations and accomplishing their study objectives, such as teaching conceptual skills.

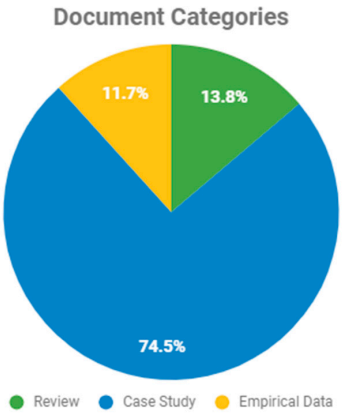

Figure 4. Document Categories.

4. Results and Discussion

After applying each of the filters described in the "Study Selection Criteria" section, as shown in Figure 1, a total of 94 studies were obtained. These studies were analyzed under different metrics, as seen in the "Data Synthesis" section. Based on our review of these studies, we now answer our research questions, considering those studies that are relevant to the specific context of each question.

RQ1. In what way does the use of technology contribute to the education of people with autism spectrum disorder?

As mentioned in the previous sections, ASD is a condition that is categorized as a disability due to the cognitive disorders that people with ASD face [13]. Several studies showed that most people with autism show a natural affinity for technology and a good disposition for using technology and learning through the use of computers [14]. This is because the environment and context that these experiences provide are predictable and structured, which helps people with ASD to maintain their routines and repetitive behaviors without affecting their comfort [15].

Several studies proposed the use of modern technologies to help teach skills to people with ASD. Some interesting examples of new technological approaches are the use of sensors, virtual reality, virtual agents, augmented reality, geolocation, and Kinect, as presented in the following studies. Wojciechowski et al. [15] developed a mobile application that, in conjunction with the use of Estimote Beacon sensors to identify objects, supports children with ASD in pronouncing new words and identifying their meanings. Lorenzo et al. [16] proposed an application that uses virtual reality and robots with cameras to detect children's emotions, adapt system interactions and thus develop social skills in students with autism spectrum disorder. Bernardini et al. [17] presented ECHOES, which is a serious game that focuses on the development of activities to promote social communication in children with ASD using an autonomous virtual agent that acts as a companion for children during their interactions with the system. Sorce et al. [18] developed an exploratory study to evaluate the effectiveness of the use of Kinect as a tool to allow people with ASD to explore works of art in a touchless virtual environment and assess whether this generates greater interest in them. Escobedo et al. [19] presented the Mobile Social Compass (MOSOCO) application, which makes use of augmented reality through a mobile device camera to include game elements in real social situations with the aim of developing social skills in children with ASD. Silva et al. [20] presented a serious game that, through geolocation, virtual reality and augmented reality, creates a virtual environment with 3D virtual monsters positioned all over the world that aim to teach children with ASD relevant educational content, such as vocabulary.

In addition to examining the studies from a technological perspective, we categorized the 94 studies based on the following learning topics with the goal of understanding the contribution of technology to education for people with ASD in terms of the specific skills that they focus on teaching: Conceptual Skills (subtopics: Language, Money, Colors, Mathematics, Programming, and Science), Practical Skills (subtopics: Health, Daily Life, and Transportation), Social Skills (subtopics: Communication, Emotions, and Interpersonal Relationships) and General Skills (subtopic: General). Table 5 shows the percentage of studies for each of the topics and subtopics, and in the same way, Table A1 (available in Appendix A) details each of the topics and subtopics according to which the articles were categorized. The results obtained after categorizing the studies are presented in the following sections.

Table 5. Learning Topic.

Topic	Subtopic	Percentage by Subtopic	Percentage by Topic
Conceptual Skills	Language	14.89%	25.53%
	Money	1.06%	
	Colors	1.06%	
	Math	5.32%	
	Programming	2.13%	
	Science	1.06%	
Practical Skills	Healthcare	2.13%	8.51%
	Daily Living	3.19%	
	Transportation	3.19%	
Social Skills	Communication	9.57%	36.17%
	Emotions	12.77%	
	Interpersonal Relationships	13.83%	
General Skills	General	29.79%	29.79%

4.1. Conceptual Skills

First, 25.53% of the studies focused on analyzing and fostering skills within the range of Conceptual Skills. Studies in the Language subcategory focused on promoting the learning of expressions, thoughts and feelings through words. Examples of this include studies [13,21]. Arciuli and Bailey [13] analyzed a small group of children with ASD that were literate using the ABRACADABRA application and observed significant improvements in reading accuracy in participants who interacted with the system but not in children who did not use the application. For the children who did not use the application, their lack of improvement was believed to be due to their lack of socialization aspects that children must exhibit when interacting with a teacher to develop reading ability. Khowaja et al. [21] developed a prototype of a serious game for children with ASD to learn vocabulary. The effectiveness of the game was assessed through the comparison of children's performance at the beginning of the intervention, after the use of the prototype and 1–2 weeks after the use of the prototype, which enabled the researchers to track the improvement in the children's vocabulary.

Another subcategory of Conceptual Skills is the Money subcategory and only one study [22] was assigned to this subcategory. Caria et al. presented the design of a game that helps people with autism spectrum disorder acquire skills to help them understand the concept of money and its applications in real life, which was tested by obtaining positive and promising results.

In addition, like the Money subcategory, the Colors subcategory also included only one study, [23]. In this study, based on cognitive theories, Tuğbagül et al. developed a computer interface for students with ASD and mild mental disability that used their preferred colors and helped them maintain their concentration.

Additionally, the studies in the Math subcategory aimed to develop skills related to numbers. Examples of studies in this subcategory are [24,25]. Tashnim et al. [24] developed the Play and Learn Number (PLaN) application, which teaches arithmetic and calculus to children who have ASD and helps children memorize and recognize numbers (in or not in sequences) through animated images. Muñoz-Soto [25] developed an application to support professionals in teaching functional mathematics and calculus to children with ASD. Through tests, it was possible to demonstrate that this application promotes the development of mathematical skills. However, it was suggested that the application should be tested by more users and in different institutions.

The Programming subcategory included studies that aimed to develop skills related to computational programming, for example, to design and order actions and commands. Only two studies were assigned to this subcategory, i.e., [26,27]. Eiselt and Carter [26] planned and conducted programming classes through Scratch for children with ASD with the aim of developing their technical and social skills. Despite their efforts, no real evidence of an increase in students' social learning or behavior was found. However, while the students did not develop social skills as expected, the authors suggested that the students knew more about programming after the experiment since at the beginning, they did not have any notion of programming, but after the experiment, they could read and write processing programs. Schmidt and Beck [27] proposed a learning intervention based on digital games for young people with ASD to develop their social skills as they worked on teams to solve introductory computer programming problems with virtual and programmable robots. According to the authors, this intervention has the potential to help participants develop social skills, however, because this study was only concerned with the initial stages of development, there was no analysis of the data, so conclusions regarding cognitive skills could not be made with certainty.

Finally, the studies in the Science subcategory investigated and interpreted natural, social, and artificial phenomena. For this subcategory, we found only one study [28], in which Eder et al. developed a mobile game application as a complementary learning material to teach children with ASD parts of the human body. After the intervention, it was observed that the application was very useful for teaching and that the motivation levels of the participants increased significantly.

4.2. Practical Skills

Second, the Practical Skills category included only 8.51% of the identified studies and was subdivided into several subcategories. First, the Healthcare subcategory concerned teaching about the health care that people should have. An example of a study in this subcategory is [29]. De Urturi et al. [29] developed a system consisting of a set of serious games aimed at teaching first aid (such as what to do in certain situations and basic knowledge about medical care and medical specialties) to people with ASD. Because the application was still in development, only partial results were available, so to determine if these results were promising, the authors administered a simple questionnaire to the participants, as they obtained positive results, they decided to continue developing the project.

Another subcategory of Practical Skills is the Daily Living subcategory. The studies in this subcategory focused on building knowledge about the development of daily recurring activities, and examples are [30,31]. Pérez-Fuster et al. [30] analyzed the impact of an intervention with digital technology (DT) compared to that of a treatment-as-usual (TAU) intervention on adults with ASD. The DT intervention sought to improve daily life skills, such as washing dishes and washing clothes. The results showed that the DT intervention significantly improved the daily life skills of the participants and was more effective than the TAU intervention. Santarosa and Conforto [31] presented a tablet application for children with ASD and children with intellectual disability (ID) that seeks to teach and develop routines in the classroom and verbal communication by directly involving teachers and assistants in schools. Children with ASD successfully adapted to the application, and their socioadaptive behaviors both in the classroom and related to verbal communication improved greatly. On the other hand, children with ID did not achieve autonomous use of the application, and they only had improvements in nonverbal classroom routines.

The final subcategory within the Practical Skills category is the Transportation subcategory. The studies in this category were concerned with teaching the necessary knowledge that individuals need to be able to transport themselves effectively. Some examples of this are found in [32,33]. McKissick et al. [32] investigated the impact of a computer instruction package to teach map-reading skills to three elementary students with ASD. Very promising results were obtained for interventions that used technology with children with ASD, such as increased levels of learning and improved learning habits among students. De Los Rios [33] proposed a draft of a study to evaluate platforms and interfaces that help users transport themselves, such as Google Maps or Apple Maps with eye tracking. They compared these platforms and interfaces with a proposed system that would provide a more personalized environment that is adapted and accessible to the needs of people with ASD.

4.3. Social Skills

Third, the Social Skills category included 36.17% of the total resulting studies and was subdivided into three subcategories. The studies in the first subcategory, Communication, focused on the development of skills such as exchanging information between two or more individuals and examples from this subcategory are found in [34,35]. Milne et al. [34] investigated the use of autonomous virtual humans (self-directed) to teach and facilitate the practice of basic social skills in greetings, conversation, listening, and shifts in conversation to people with ASD. The results were positive, as users increased their knowledge and development of social skills. In addition, it has been indicated that this approach was well received by participants and caregivers. Ribeiro and Barbosa [35] developed a game called ComFiM, which aims to encourage communication between people with severe degrees of autism. The game was evaluated based on the perceptions of the interlocutors of each player and the communication intentions observed between the players to collaborate with each other and the results showed that the application positively influenced the communication intentions of the players.

The Emotions subcategory included studies that examined the development of skills such as the identification of facial emotions. Some studies from this subcategory are [36,37]. Romero [36] carried out a computer-based intervention to teach the recognition of emotions to students with communication and social skill deficits. All participants showed improvements when assessing and

recognizing emotions on faces, but it was suggested that the effectiveness of the intervention should be tested in a larger population. Christinaki et al. [37] presented a serious game with a natural user interface (NUI) interaction that aims to teach young children with ASD to recognize and understand different facial emotions. The authors concluded that technological interventions with NUI improve the learning process and indicated that the emotional state of the players is directly related to their learning skills.

Additionally, the studies in the Interpersonal relationships subcategory emphasized individuals' development of relationships. Some of the studies that were assigned to this subcategory are [38,39]. Boyd et al. [38] described how collaborative assistance technologies, such as the Zody collaborative game, can be used to facilitate social relationships in children with ASD. They discussed how design can foster three levels of social relationship, i.e., membership, partnership, and friendship, even without the help of adults. The results indicate that collaborative technologies provide support for the development of social skills at different levels of intimacy between players without a mediator during the intervention. Hourcade et al. [39] conducted an intervention with multitouch tablets with children with ASD to promote their social skills and help them develop their creativity, alter their interests, and be able to understand emotions. The result of the intervention was that it increased pro-social behaviors, such as collaboration, coordination, and interest in social activities, in children with ASD.

4.4. General Skills

Finally, the General Skills category included 29.79% of the studies. As this category referred to a range of topics, we defined only one subcategory, the General subcategory; some example studies are [40,41]. Backman et al. [40] investigated a method of evaluating children on the autism spectrum through computer games, which provide an objective, motivating, and safe evaluation of the participants. Although more research was recommended, the results showed that computer games have great potential in special education as an evaluation tool to clarify the difficulties associated with ASD. Hulusic and Pistoljevic [41] presented the initial development process of the LeFCA framework, which was used to teach children with ASD basic skills and concepts. LeFCA consists of four games that focus on developing basic skills (such as labeling, pointing and pairing in reference to visual and auditory stimuli) necessary for learning. Each of the participants was constantly motivated to play, and the skills learned could be extrapolated to new media or environments without the need for any training.

After reviewing all the studies and classifying them based on their learning topics, as shown in Table 5, we can see that there are a few studies that used modern and/or complex technologies, such as virtual reality or sensors. These technological approaches are interesting examples of how this area is developing in innovative ways.

Notably, most of the studies focused on teaching Social Skills, such as Emotions (12.77%), Communication (9.57%), and Language (14.89%), which are the most important areas that people with ASD have difficulties with.

RQ2. Which user experience and accessibility elements/methods are considered when analyzing the impact of technology on people with autism spectrum disorder?

Although many of the studies suggested that accessibility and user experience are fundamental concepts for interventions with people who have ASD, these aspects were not treated with the importance that they should be.

Several of the studies that were reviewed from the pool of articles reported having used and/or considered user experience and/or accessibility, but most of these studies did not provide enough detail about the use of these concepts. Table A2 (available in Appendix A) shows a total of 23 studies that in some way used and/or provided "detail" on the use of these concepts in their research. We can see that the most recurrent terms used in the studies were user experience, usability, and accessibility.

For instance, many of the studies claimed to have focused on accessibility when developing touchscreen applications, such as [23,24,39,42,43]. However, the authors' affirmations were not supported by empirical evidence or other details.

On the other hand, other studies such as [27,33] proposed the evaluation of the usability and/or user experience of the systems in future works. De Los Rios [33] suggested evaluating the usability of the application based on eye tracking. Schmidt and Beck [27] proposed the use of eye-tracking, electroencephalogram (EEG) scanning, and focus group interviews to evaluate the usability of the system.

Studies such as [28,40,42,44,45] aimed to evaluate usability and user experience based on post-intervention questionnaires with users, as well as with the people around them (such as their teachers or parents). These studies worked with control and test groups of children with and without ASD. Few studies indicated the number of subjects involved in the experiments: 14 in [42], 11 in [28], and 30 in [40]. Forty teachers were also involved in the experiment described in [42]. In addition to the questionnaires, Santarosa and Conforto [45] and Backman et al. [40] carried out methods such as focus groups in their interventions to be able to evaluate the usability and user experience.

Additionally, in studies such as those by Khowaja and Salim [46] and Naziatul et al. [47], the proposed systems were evaluated based on heuristic evaluations. In these studies, the authors adapted the heuristics proposed by Nielsen [48] to the contexts of their interventions. In both cases, three experienced evaluators assessed the system usability.

In addition, in the study by Vallefuoco et al. [49], a usability user test was carried out with 10 children aged between 5 and 12 under the methodology proposed by Moreno Ger [50] to evaluate the system, its usability, and the effectiveness of the customized elements developed to fulfill the objective of the study.

Finally, Caria et al. [22] worked with children with ASD between 16 and 22 years old, and Almeida et al. [51] worked with 40 children between 3 and 13 using the "System Usability Scale" (SUS) to evaluate the usability of their applications.

As we can see, few studies provided details about how they used concepts such as usability, user experience and accessibility, how these concepts were evaluated, and what kind of users were involved in their experiments. We think that it is important to consider all these concepts when developing new solutions.

RQ3. Which game elements are considered when using gamification or serious games in the education of people with autism spectrum disorder?

Several of the identified studies described the use of game-based learning (mostly serious games), but they did not specify and/or provide details about the elements of the games that were used. However, a significant number of studies explicitly presented some game elements that allow these systems to be more attractive and engaging for users. In Table A3 (available in Appendix A), we can see the game elements used in the studies, where the most frequent elements were points, levels, and rewards. Brief definitions of the game elements, as presented by Werbach [10], are presented in Section 2.5.

For example, Vallefuoco et al. [49] analyzed a serious game that focused on improving math skills in children with ASD and for which one of the main elements was feedback. Likewise, Sorce et al. [18] used avatars in an application with Kinect to foster the interest of participants with ASD in digital representations of works of art, paintings, and sculptures. In addition, Romero [36] carried out a computer-based intervention with intrinsic rewards and points to teach the recognition of emotions. Similarly, Chen et al. [52] designed and developed a computer game with points and rewards to develop and evaluate emotional skills and conceptual comprehension skills (such as recognizing fruits) in children with autism spectrum disorder. Additionally, Harrold et al. [53] added to the concepts described above through the use of levels in CopyMe, a serious game for iPad, which provides children with ASD with a means to learn emotions through observation and mimics. In the same way, Sturm et al. [42] used stories in addition to rewards, points, and levels in a game with Kinect technology that aims to promote the recognition of emotions and encourage collaboration between people with ASD and their peers. Finally, Boyd et al. [38] described the use of Zody, as a collaborative

assistance application, to teach social relations to children with ASD through the use of collaboration, points, levels, and rewards.

Most of the studies considered in this review did not explicitly identify which game elements they used in the development of their solutions. Even when they did, they did not give enough details on the effectiveness of the specific game elements. Although some authors claimed that their users were more engaged with the solutions they proposed, they did not provide empirical evidence to support such claims.

5. Conclusions and Future Work

Our systematic literature review focuses on analyzing the impact of technology on people with autism spectrum disorder based on research published during the last 10 years and available on the relevant scientific databases. The analysis shows an increase in the papers published on this topic over the years, which indicates an increasing research interest in the area. Interestingly, the highest percentage of the papers presented are case studies (74%). The studies were categorized into four categories: Conceptual Skills, Practical Skills, Social Skills, and General Skills. Studies that focus on Social Skills are predominant (36.17%).

Regarding RQ1, we observe that new research has focused on supporting children with ASD by using technologies such as virtual reality, augmented reality, virtual agents, sensors, and geolocation through educational games. These studies emphasize teaching different skills to people with ASD in educational contexts, with a higher percentage of studies focusing on Social Skills (36.17%) than on Conceptual (25.53%) or Practical Skills (8.51%), which shows a need for more research and development of new solutions for teaching such important topics. Exploring these alternatives and expanding the technological solutions to teach skills to people with ASD seem to be promising research topics.

The results related to RQ2 show that several studies mention that aspects such as user experience, usability, and accessibility are crucial when working with people with ASD. However, these aspects are usually not considered or validated in detail. Although the use of new technologies, such as EEG scanning and eye tracking in [27], to evaluate the usability of their systems is indeed interesting, studies have shown that brain activity may be negatively correlated with the Asperger questionnaire [54] and may be weaker for individuals with ASD when observing other people's actions [55]. Future studies should be careful with the use of such technological approaches, as brain activity may be misleading when working with people with ASD, especially in tasks that require recognizing emotions from facial expressions or movements. We believe that user experience is important and that future studies should consider accessibility and usability tests to ensure positive experiences and comfort with the use of their solutions, as there is a lack of research that applies these concepts correctly and that provides details about the user groups that participate in interventions.

Regarding RQ3, we have observed in the literature that game elements are a good way to engage users with learning and enhance the effectiveness of teaching approaches for people with ASD, but our findings show that there is a lack of evidence about the effect of the use of game elements in gamification, e-learning, and serious game solutions. We believe that future studies should consider and validate the use of game elements. Werbach [10] highlighted that game elements are effective, have a positive relation with users' engagement, and have been widely used with promising results.

We think that the use of technologies in conjunction with suitable game elements and user experience and accessibility design and evaluation are promising research topics related to teaching people with ASD.

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Appendix A

Table A1. Identified Learning Topics.

Topic	Subtopic	Authors
Conceptual Skills	Language	Arciuli. J, Bailey. B. (2019) [13]
		Lin. C, Chang. S, Liou. W, Tsai. Y. (2013) [14]
		Wojciechowski. A., Al-Musawi. R. (2017) [15]
		Magaton. H, Bim. Silvia. (2017) [56]
		Mendonça. V, Coheur. L, Sardinha. A. (2015) [44]
		Wilson. C, Brereton. M, Ploderer. B, Sitbon. L. (2018) [57]
		Alvarado. C, Muñoz. R, Villarroel. R, et al. (2017) [58]
		Rasche. N, Pourcho. J, Wei. S, Qian. C.Z., Chen. V.Y. (2013) [59]
		Cunha. R.M., Barbosa. S.D.J. (2012) [60]
		Gomez. J, Jaccheri. L, Torrado. J.C, Montoro. G. (2018) [61]
		Khowaja. K, Salim. S.S, Al-Thani. D. (2018) [62]
		Khowaja. K, Salim. SS. (2019) [46]
		Khowaja. K, Al-Thani. D, Salim. SS. (2018) [21]
		Frutos. M, Bustos. I, Zapirain. B.G, Zorrilla. A.M. (2011) [63]
	Money	Caria. S, Paternò. F, Santoro. C, Semucci. V. (2018) [22]
	Colors	Tuğbagül Altan. N, Göktürk. M. (2018) [23]
	Math	Aziz. N.S.A, Ahmad. W.F.W, Hashim. A.S. (2016) [64]
		Naziatul. A.A, Wan. W.A, Ahmad. H. (2016) [47]
		Tashnim. A, Nowshin. S, Akter. F, Das. A.K. (2018) [24]
		Muñoz-Soto. R, Becerra. C, Noël. R., et al. (2016) [25]
		Aziz. N.S.A, Ahmad. W.F.W, Zulkifli. N.J.B. (2015) [65]
	Programming	Eiselt. K, Carter. P. (2019) [26]
		Schmidt. M, Beck. D. (2016) [27]
	Science	Eder. MS, Díaz. JML, Madela. JRS, Mag-usara. MU, Sabellano. DDM. (2016) [28]
Practical Skills	Healthcare	De Urturi. ZS, Méndez. A, García. B. (2011) [29]
		De Urturi. ZS, Méndez. A, García. B. (2012) [66]
	Daily Living	Pérez-Fuster. P, Sevilla. J, Herrera. G. (2019) [30]
		Santarosa. L.M.C, Conforto. D. (2016) [31]
		Lee. D, Frey. G, Cheng. A, Shih. PC. (2018) [67]
	Transportation	McKissick. B, Spooner. F, Wood. C.L, Diegelmann. K.M. (2013) [32]
		De Los Rios. P. C. (2018) [33]
		Rector. K. (2018) [68]

Table A1. *Cont.*

Topic	Subtopic	Authors
Social Skills	Communication	Milne. M, Raghavendra. P, Leibbrandt. R, Powers. D.M.W. (2018) [34]
		Bringas. J.A.S, León. M.A.C, Cota. I.E, Carrillo. A.L. (2016) [69]
		Hussain. A, Abdullah. A, Husni. H, Mkpojiogu. E.O.C. (2016) [70]
		Bernardini. S, Porayska-Pomsta. K, Smith. T.J. (2014) [17]
		Tang H.H, Jheng. C.M, Chien. M.E, Lin. N.M, Chen. M.Y. (2013) [71]
		El-Seoud. M.S.A, Karkar. A.G, Al Ja'am. J.M, Karam. O.H. (2015) [72]
		Baldassarri. S, Passerino. L, Ramis. S, Riquelme. I, Perales. FJ. (2018) [73]
		Cabielles-Hernández. D, Pérez-Pérez. J.-R, Paule-Ruiz. M, Fernández-Fernández. S. (2017) [74]
		Ribeiro. PC, Fox. AB. (2014) [35]
	Emotions	Romero. N.I. (2017) [36]
		Sturm. D, Kholodovsky. M, Arab. R, et al. (2019) [42]
		Papoutsi. C, Drigas. A, Skianis. C. (2018) [75]
		Lorenzo. G, Lledó. A, Pomares. J, Roig. R. (2016) [16]
		Leijdekkers. P, Gay. V, Wong. F. (2013) [76]
		Tinnunnem. S.G, Shah. G, Lahiri. U. (2017) [77]
		Harrold. N, Tan. C.T, Rosser. D, Leong. T.W. (2014) [53]
		Hyun. P.J, Abirached. B, Zhang. Y. (2012) [78]
		Castillo, T.A, Pérez de Celis. C, et al. (2016) [79]
		Almeida. LM, Silva. DPD, Theodório. DP, et al. (2019) [51]
		Cisnero. A.Q, Juárez-Ramírez. R., Figueroa. A.M. (2016) [80]
		Christinaki. E, Vidakis. N, Triantafyllidis. G. (2014) [37]
	Interpersonal Relationships	DiGennaro. F.D, Hyman. S.R, Hirst. J.M. (2011) [81]
		Boyd. L.E, Ringland. K.E, Haimson. O.L, Fernandez. H, Bistarkey. M, Hayes. G.R. (2015) [38]
		Muñoz. R, Morales. C, Villarroel. R, Quezada. A, De Albuquerque. V.H.C. (2019) [82]
		Rapp. A, Cena. F, Castald., R, Keller. R, Tirassa. M. (2018) [83]
		Sturm. D, Gillespie-Lynch. K, Kholodovsky. M. (2017) [84]
		Escobedo. L, Nguyen. D.H, Boyd. L.A, et al. (2012) [19]
		Hourcade. J.P, Bullock-Rest. N.E, Hansen. T.E. (2012) [39]
		Grossard. C, Grynspan. O, Serret. S, Jouen. A.L, Cohen. D. (2017) [85]
		Hughes. D.E, Vasquez E, Nicsinger. E. (2016) [86]
		Hani. H, Abu-Wandi. R. (2015) [87]
		Dehkordi. SR, Rias. RM. (2015) [88]
		Aziz. MZA, Abdullah. SAC, Adnan. SFS, Mazalan. L. (2014) [89]
		Jeekratok. K, Chanchalor. S, Murphy. E. (2014) [90]

Table A1. *Cont.*

Topic	Subtopic	Authors
General Skills	General	Backman. A, Mellblom. A, Norman-Claesson. E, Keith-Bodros. G, Frostvittra. M, Bölte. S, Hirvikoski. T. (2018) [40]
		Hong. E.R, Gong L.Y, Ninci. J, Morin. K, L.Davis. J, Kawaminami. S, Shi Y.G, Noro. F. (2017) [91]
		Still. K, May. R.J, Rehfeldt. R.A, Whelan R, Dymond. S. (2015) [92]
		Smith. K, Abrams. SS. (2019) [93]
		Cinquin. P.-A, Guitton. P, Sauzéon. H. (2019) [94]
		Jingga. F, Meyliana. Hidayanto. AN, Prabowo. H. (2019) [95]
		Constain. M. GE, Collazos O.C, Moreira. F. (2019) [96]
		Chen. J, Wang. G, Zhang. K, Wang. G, Liu. L. (2019) [52] Aziz. NSA, Ahmad. WFW, Hashim. AS. (2019) [97]
		Tsikinas. S, Xinogalos. S, Satratzemi. M, Kartasidou. L. (2018) [98]
		Çorlu. D, Taşel. Ş, Turan. S.G, Gatos. A, Yantaç. A.E. (2017) [99]
		Vallefuoco. E, Bravaccio. C, Pepino. A. (2017) [49]
		Tsikinas. S, Xinogalos. S, Satratzemi. M. (2016) [100]
		Wolff. M, Gattegno. M.P, Adrien. J.-L, Gabeau. C, Isnard. P. (2014) [101]
		Marchetti. E, Valente. A. (2015) [102]
		Alarcon-Licona. S, Loke. L, Ahmadpour N. (2018) [103]
		Sorce. S, Gentile. V, Oliveto. D, Barraco. R, Malizia. A, Gentile. A. (2018) [18]
		Mazon. C, Fage. C, Sauzéon. H. (2019) [104]
		Goosen. L. (2019) [105]
		Santarosa. L.M.C, Conforto. D. (2016) [45]
		Rahman. M.R, Naha. S, Roy. P.C, et al. (2011) [106]
		Silva Sandez. G, Rodriguez Miranda. F.P. (2018) [107]
		Silva. S.D, Neto. F.M.M, De Lima. R.M, De Macedo. F.T, Santo. J.R.S, Silva. W.L.N. (2017) [20]
		Kamaruzaman. N.N, Jomhari. N. (2015) [43]
		Tsikinas. S, Xinogalos. S. (2019) [108]
		Helmi Adly. MN, Faaizah. S, Naim. CP. (2014) [109]
		Boucenna. S, Narzisi., A, Tilmont. E, et al. (2014) [110]
		Hulusic. V, Pistoljevic. N. (2012) [41]

Table A2. Identified User Experience Concepts.

Authors	Identified Concepts
Backman. A, Mellblom. A, Norman-Claesson. E, Keith-Bodros. G, Frostvittra. M, Bölte. S, Hirvikoski. T. (2018) [40]	Usability
Romero. N.I. (2017) [36]	Accessibility
Sturm. D, Kholodovsky. M, Arab. R, et al. (2019) [42]	Usability
Constain. M. GE, Collazos O.C, Moreira. F. (2019) [96]	Usability, accessibility
Muñoz. R, Morales. C, Villarroel. R, Quezada. A, De Albuquerque. V.H.C. (2019) [82]	Usability
Caria. S, Paternò. F, Santoro. C, Semucci. V. (2018) [22]	Usability, accessibility
Milne. M, Raghavendra. P, Leibbrandt. R, Powers. D.M.W. (2018) [34]	Usability

Table A2. *Cont.*

Authors	Identified Concepts
Wojciechowski. A., Al-Musawi. R. (2017) [15]	Usability
Vallefuoco. E, Bravaccio. C, Pepino. A. (2017) [49]	Usability
Naziatul. A.A, Wan. W.A, Ahmad. H. (2016) [47]	Usability
Sorce. S, Gentile. V, Oliveto. D, Barraco. R, Malizia. A, Gentile. A. (2018) [18]	Usability, accessibility
De Los Rios. P.C. (2018) [33]	Usability, accessibility
Mendonça. V, Coheur. L, Sardinha. A. (2015) [44]	User experience
Rector. K. (2018) [68]	Accessibility
Tang H.H, Jheng. C.M, Chien. M.E, Lin. N.M, Chen. M.Y. (2013) [71]	Usability, accessibility, user experience
Muñoz-Soto. R, Becerra. C, Noël. R., et al. (2016) [25]	Usability, accessibility, user experience
Santarosa. L.M.C, Conforto. D. (2016) [45]	Usability, accessibility
Khowaja. K, Salim. SS. (2019) [46]	Usability
Almeida. LM, Silva. DPD, Theodório. DP, et al. (2019) [51]	Usability, accessibility
Lee. D, Frey. G, Cheng. A, Shih. PC. (2018) [67]	Usability, accessibility, user centered
Cabielles-Hernández. D, Pérez-Pérez. J.-R, Paule-Ruiz. M, Fernández-Fernández. S. (2017) [74]	Accessibility
Schmidt. M, Beck. D. (2016) [27]	Usability
Eder. MS, Díaz. JML, Madela. JRS, Mag-usara. MU, Sabellano. DDM. (2016) [28]	Usability

Table A3. Identified Game Elements.

Authors	Game Elements Referenced
Romero. N.I. (2017) [36]	Points, intrinsic rewards
McKissick. B, Spooner. F, Wood. C.L, Diegelmann. K.M. (2013) [32]	Achievement, levels
Lin. C, Chang. S, Liou. W, Tsai. Y. (2013) [14]	Points
Bistarkey. M, Hayes. G.R. (2015) [38]	Points, levels, rewards, collaboration
Sturm. D, Kholodovsky. M, Arab. R, et al. (2019) [42]	Points, levels, rewards, narrative, collaboration
Muñoz. R, Morales. C, Villarroel. R, Quezada. A, De Albuquerque. V.H.C. (2019) [82]	Levels
Chen. J, Wang. G, Zhang. K, Wang. G, Liu. L. (2019) [52]	Points, levels, rewards
Aziz. NSA, Ahmad. WFW, Hashim. AS. (2019) [97]	Levels
Caria. S, Paternò. F, Santoro. C, Semucci. V. (2018) [22]	Levels
Milne. M, Raghavendra. P, Leibbrandt. R, Powers. D.M.W. (2018) [34]	Feedback, rewards
Sturm. D, Gillespie-Lynch. K, Kholodovsky. M. (2017) [84]	Levels, collaboration
Vallefuoco. E, Bravaccio. C, Pepino. A. (2017) [49]	Feedback
Bringas. J.A.S, León. M.A.C, Cota. I.E, Carrillo. A.L. (2016) [69]	Points, levels, feedback, rewards
Lorenzo. G, Lledó. A, Pomares. J, Roig. R. (2016) [16]	Avatars
Bernardini. S, Porayska-Pomsta. K, Smith. T.J. (2014) [17]	Avatars
Sorce. S, Gentile. V, Oliveto. D, Barraco. R, Malizia. A, Gentile. A. (2018) [18]	Avatars
Magaton. H, Bim. Silvia. (2017) [56]	Levels
Tashnim. A, Nowshin. S, Akter. F, Das. A.K. (2018) [24]	Rewards
Alvarado. C, Muñoz. R, Villarroel. R, et al. (2017) [19]	Points, levels
Muñoz-Soto. R, Becerra. C, Noël. R., et al. (2016) [25]	Points, levels
Escobedo. L, Nguyen. D.H, Boyd. L.A, et al. (2012) [19]	Points, levels, rewards
Harrold. N, Tan. C.T, Rosser. D, Leong. T.W. (2014) [53]	Points, levels, rewards
Khowaja. K, Salim. SS. (2019) [46]	Achievement, points, levels, rewards
Almeida. LM, Silva. DPD, Theodório. DP, et al. (2019) [51]	Points, levels, avatars, feedback
Lee. D, Frey. G, Cheng. A, Shih. PC. (2018) [67]	Rewards
Baldassarri. S, Passerino. L, Ramis. S, Riquelme. I, Perales. FJ. (2018) [73]	Points, levels
Hughes. D.E, Vasquez E, Nicsinger. E. (2016) [86]	Achievement, points, avatars
Schmidt. M, Beck. D. (2016) [27]	Team
Eder. MS, Díaz. JML, Madela. JRS, Mag-usara. MU, Sabellano. DDM. (2016) [28]	Levels
Dehkordi. SR, Rias. RM. (2015) [88]	Points, levels, rewards
Ribeiro. PC, Fox. AB. (2014) [35]	Levels, collaboration
De Urturi. ZS, Méndez. A, García. B. (2012) [66]	Levels, avatars

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Article

User Experience Factors for People with Autism Spectrum Disorder

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Abstract: Autism Spectrum Disorder (ASD) is a condition characterized by difficulties with social interaction and communication. Studies show that people with ASD tend to enjoy using technology, as it provides them with a safe and trustworthy environment. Evaluating User eXperience (UX) in people with disabilities has been a challenge that studies have addressed in recent times. Several studies have evaluated the usability and UX of systems designed for people with ASD using evaluation methods focused on end users without disabilities. In reviewing studies that evaluate systems designed for people with ASD, considering the characteristics of these users, we discovered a lack of particularized UX models. We present a proposal of nine UX factors for people with ASD based on two approaches: (1) the characteristics, affinities, and needs of people with ASD, and (2) design guidelines and/or recommendations provided in studies on technological systems for people with ASD and/or interventions with these users. The nine UX factors for people with ASD provide a theoretical basis from which to adapt and/or create UX evaluation instruments and methods and to generate recommendations and/or design guidelines that are adequate for this context.

Keywords: user experience; user experience attributes; user experience factors; user experience models; autism spectrum disorder

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1. Introduction

The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [1] defines Autism Spectrum Disorder (ASD) as a developmental disorder that affects people's communication and behavior. Additionally, it is established that ASD is a condition characterized by deficits in two core domains: (1) social communication and social interaction and (2) restricted repetitive patterns of behavior, interests, and activities.

Several studies have developed and evaluated User eXperience (UX) in systems for people with ASD. These studies have focused on evaluating UX using various methods available in the literature such as focus groups, eye tracking, heuristics evaluation, and questionnaires after interactions with the systems, which do not present sufficient details for evaluations. There is a lack of empirical evidence in their research, as described by a previous systematic literature review [2].

In a second literature review [3], we found studies that propose different characteristics to consider when working with people with ASD as well as others that propose guidelines and/or recommendations for designing systems for these users. However, no study presents particular UX factors for people with ASD. We think that it is important to consider a set of specific UX factors that could facilitate UX evaluation and design.

This is why, taking into account the works previously found in the literature [2,3] as well as new studies added for this research, we have designed a proposal of nine UX factors for people with ASD based on two approaches: (1) the characteristics, affinities, and needs of people with ASD, and (2) design guidelines and/or recommendations provided by studies focused on technological systems for people with ASD and/or interventions with

these users. The nine proposed UX factors are focused on evaluating systems designed for adults with ASD of severity level 1, "Requiring support", as defined by the DSM-5 [1].

This document is organized as follows: Section 2 presents a theoretical background; Section 3 describes relevant related work; Section 4 introduces and describes the process used to create a preliminary proposal of UX factors for people with ASD; Section 5 presents the final set of nine UX factors for people with ASD; and Section 6 presents a discussion.

2. Theoretical Background

Below are brief descriptions of ASD, UX, and UX models, which are relevant for this investigation.

2.1. Autism Spectrum Disorder

ASD is defined in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [1] as a condition characterized by deficits in two core domains: (1) social communication and social interaction, and (2) restricted repetitive patterns of behavior, interests, and activities. Additionally, people with ASD may or may not present secondary symptoms such as intellectual disability (ID), low tolerance for frustration, no verbal language, motor difficulties, and others. Three severity categories for ASD have been established [1] depending on the degree of support that the person requires and range from level 1 "Requiring support" to level 3 "Requiring very substantial support."

2.2. User Experience

Standard ISO 9241-210 [4] defines user experience as a "user's perceptions and responses that result from the use and/or anticipated use of a system, product or service." Additionally, the standard describes UX as "users' perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviors, and accomplishments that occur before, during and after use." A component of UX is usability, a concept defined by the ISO 9241-11 standard [5] as the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."

2.3. UX Models

Multiple authors have defined UX and usability models focused on providing indicators to measure "satisfaction" in the interaction between the user and the system or product. Some examples include (1) Guidance on Usability from The International Standard on Ergonomics of Human System Interaction [5], which defines three aspects to consider: effectiveness, efficiency, and satisfaction; (2) Jacob Nielsen's model [6], which describes five attributes to consider: learnability, efficiency, memorability, errors, and satisfaction; (3) Llúcia Masip et al.'s model [7], which describes eleven facets to consider: dependability, usability, playability, accessibility, plasticity, communicability, cross-cultural capacity, emotionality, desirability, usefulness, and findability; and (4) Peter Morville's model [8], which presents seven factors that help users have a meaningful and valuable user experience: useful, usable, desirable, findable, credible, accessible, and valuable.

3. Related Work

In a previous study [2], we analyzed the impact that technology has on people with ASD. One of the research questions answered in this research was "Which user experience and accessibility elements/methods are considered when analyzing the impact of technology on people with autism spectrum disorder?". We found a lack of empirical evidence and details from studies evaluating user experience and/or usability in systems designed for people with ASD.

After the systematic literature review carried out previously [2] and a review of the literature at present, we found studies that have evaluated the user experience and/or usability in systems designed for people with ASD. Some studies [9–11] mention having

carried out focus groups, and other studies [9,12,13] propose the use of eye tracking. In ref. [10,11,14–17], the authors distribute questionnaires to users after having interacted with the systems, and in the same way, studies such as [18–20] evaluate the usability of systems through the use of the "System Usability Scale" (SUS) [21] or SUS-ASD [22].

Vallefuoco et al. [23] evaluated the usability of their software system based on Moreno Ger's methodology [24], which facilitates usability tests for serious games. Furthermore, studies [25–27] claim to have evaluated the usability of their systems designed for people with ASD based on an analysis of observations, through the collection of comments, and/or with the help of experts in the domain of people with ASD. On the other hand, studies such as Naziatul et al. [28] propose evaluating the usability of systems for people with ASD through adaptations of the Nielsen heuristics [29]. Furthermore, studies such as [15,30–33] claim to have developed systems for people with ASD with a focus on accessibility given by the use of touch screens.

These studies do not present empirical evidence or details that formalize the process of evaluating the user experience with systems designed for people with ASD. Additionally, no studies formally specify the attributes/factors/aspects of UX for systems designed for people with ASD, which we believe would provide a basis for formalizing the evaluation process. However, studies do identify the creation and/or use of design guidelines that characterize people with ASD as a means to develop systems for said people in different contexts, which can be a starting point for creating UX factors tailored to people with ASD. Below are studies that define design guidelines based on the characteristics of people with ASD.

3.1. Technology-Related Research

As described in [2], some studies have focused on proposing design guidelines for technological systems for people with ASD based on reviews of the literature and the characteristics of the users. Research has focused on creating/proposing design guidelines focused on tactile and nontactile systems for serious games and/or systems designed to develop learning skills in people with ASD.

In our previous study [3], a total of eleven studies focused on developing social skills were analyzed to propose design guidelines and best practices for future technological interventions in people with ASD. Here, a total of seven design guidelines are proposed: (1) structured and predictable learning environments; (2) generalization to daily life, (3) learning dynamics: individual and collaborative; (4) engagement through activity cycles and game elements; (5) error management; (6) mixed activities; and (7) no-touch and hybrid interfaces.

In ref. [34], a set of design guidelines for motion-based touchless interaction for medium-low functioning children with ASD are proposed. These design guidelines were developed based on empirical studies and collaborations with therapeutic centers. This set of design guidelines has been classified into two categories, the first of which is related to general aspects of interface/interaction and the second of which considers specific aspects according to the expected learning objectives, which in turn have been classified into the motor, cognitive, and social dimensions.

In ref. [35], the distances and sizes of pixels of the objects that systems for people with ASD use are established. The authors point out that 57 pixels is the minimum target size that touch systems must apply for users with ASD.

Studies such as those by Stavros Tsikinas and Stelios Xinogalos [36,37] and Stéphanie Carlier et al. [38] propose and/or compile design guidelines available in the literature on serious games for people with ASD. In ref. [36], a total of seven design guidelines for serious games for people with ASD are proposed based on existing design guidelines given in the literature: (1) feedback, (2) customization and personalization, (3) graphical interface, (4) game difficulty, (5) repetition, (6) motivators, and (7) participatory design. The authors in [37] compiled and created design guidelines for serious games that aim to improve life skills in young adults with ASD and intellectual disability (ID). After a

review of the literature, the authors define a "game design framework" that focuses on three axes: (1) pedagogy, (2) learning content and game mechanics, and (3) evaluation. In the research by Carlier et al. [38], serious games were created to reduce stress and anxiety in parents and children with ASD, and for their creation, eleven design guidelines found in the literature and six design guidelines based on the experiences of specialized therapists were considered.

3.2. UX-Related Research

Studies have proposed the creation of design guidelines for focused systems for people with ASD considering aspects such as usability, accessibility, and task-centered user interface design (TCUID) based on reviews in the literature and the characteristics of said users.

In ref. [39], Chung and Ghinea discuss the use of technology to support the development of empathy in children with autism. Based on a review of the literature, a total of ten design guidelines are proposed and classified into four categories: graphical layout, navigation and structure, language, and interaction. The system was designed based on a human-centered design, and its acceptability and usability were evaluated through interviews, a survey of 12 sentences created based on the system usability scale (SUS) [21], defined design guidelines, and open-ended questions.

In a study by Khowaja and Salim [40], a total of 15 heuristics were defined based on Nielsen heuristics [29] and a compilation of 70 guidelines for the design and development of systems for children with ASD. These design guidelines were compiled after a review of the literature [41–43].

Hailpern et al. [44] described a real-time voice display system for people with ASD and speech delays (SPDs). The system was designed based on task-centered user interface design (TCUID), and after experiments and a review of the existing literature, a total of seven design guidelines were created. The proposed design guidelines are as follows: (1) minimize delay to interaction, (2) real-time is fun, (3) child customization, (4) dynamic computer correction, (5) robust microphone setup, (6) competence of the child, and (7) physical interaction.

Raymaker et al. [45] proposed a set of accessibility guidelines for websites used by people with ASD based on a website aimed at improving access to health care for autistic adults. The authors declare that they propose these accessibility guidelines based on the theory of accessibility and evaluate usability through evaluation surveys. A total of 20 accessibility guidelines are provided and are classified into three categories: physical accessibility, intellectual accessibility, and social accessibility.

In ref. [46], a systematic review of the literature is employed to define a set of recommendations for the development of software solutions adapted for people with ASD. The set of recommendations, called AutismGuide, includes a total of 69 recommendations categorized into 11 categories: (1) general usability principles, (2) nonfunctional requirements, (3) functional requirements, (4) adaptability, (5) guidance, (6) workload, (7) compatibility, (8) explicit control, (9) significance of codes, (10) error management, and (11) consistency.

Tan-MacNeilla et al. [47] evaluated whether parents of children with neurodevelopmental disorders (NDD) perceived the Better Nights, Better Days (BNBD) intervention as usable, acceptable, and feasible. To evaluate these aspects, the authors created questionnaires for before and after the intervention, which were completed by the users. The questionnaires were developed based on Morville's honeycomb model [8].

3.3. Nontechnological Intervention-Related Research

Studies have proposed different sets of design guidelines to be applied in places frequented by people with ASD. In Barakat et al. [48], a set of design guidelines is proposed to design a therapeutic garden for children with ASD with the objective of calming hyperreactive children and stimulating hyporeactive children with ASD. The design guidelines proposed by Barakat et al. [48] are classified under four categories: (1) visual principles as

a therapeutic tool, (2) design elements as a therapeutic tool, (3) physical landscape features as a therapeutic tool, and (4) design guidelines, where the latter includes recommendations for security and safety and motor skills. McAllister and Maguire [49] proposed a total of 16 design guidelines for designing ASD-friendly classrooms. The 16 design guidelines specify the features of school environments that users interact with should include.

Although this research focuses on proposing UX factors to be used in technologies used by people with ASD, we believe that concepts such as promoting secure and safe environments and providing a transitional buffer before entering a classroom, among other characteristics, are necessary in any context that people with ASD interact with.

4. A Two-Step Preliminary Proposal of UX Factors for ASD

Given the need to formalize the user experience evaluation process in systems focused on people with ASD, a methodical process was carried out to make a preliminary proposal of user experience factors for people with ASD that consider their characteristics, difficulties, and/or affinities, as found in the literature. The preliminary proposal of user experience factors was created following two steps, which are detailed below.

4.1. Step 1: Adapting Morville UX Factors Based on ASD Characteristics

As shown in Figure 1, a preliminary proposal of specific UX factors for people with ASD is defined based on (i) a search of the literature of the characteristics, difficulties, and/or affinities of people with ASD, and (ii) the collection and selection of UX factors/attributes.

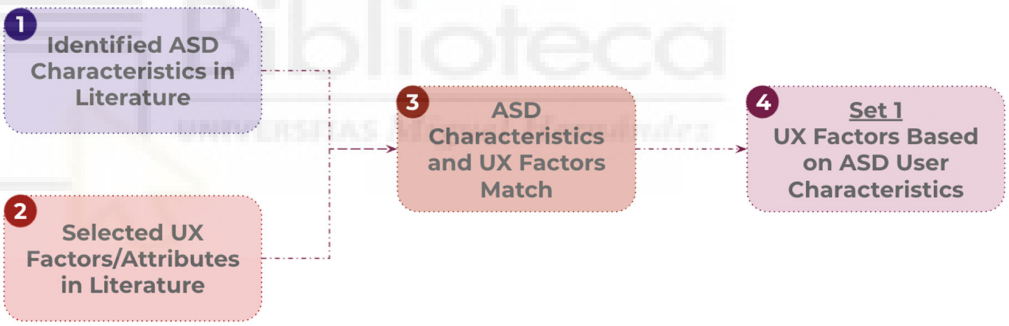

Figure 1. Process for Defining UX Factors Based on ASD User Characteristics.

To perform this specification, we followed a four-step process to define specific UX factors for people with ASD: (1) the collection and grouping of characteristics, difficulties, and affinities in people with ASD; (2) the collection and selection of UX factors/attributes found in the literature; (3) matching identified characteristics and UX factors; and (4) the proposal of UX factors for people with ASD. Each step is detailed below.

4.1.1. Collection and Grouping of Characteristics/Difficulties/Affinities for People with ASD

In this step, we compiled and grouped the characteristics, difficulties, and affinities of people with ASD found in previous work [2,3] and information provided by the book Diagnostic and Statistical Manual of Mental Disorders [1]. Following this process, we compiled a set of 18 characteristics, difficulties, and affinities, which are shown in Table 1.

Table 1. ASD Characteristics from the Literature.

Characteristics/Difficulties/Affinities of People with ASD
People with autism spectrum disorder (ASD) tend to enjoy themselves and be engaged when interacting with computers, as these interactions occur in a safe and trustworthy environment [2].
People with ASD have a tendency to engage in visual and structured thinking [50].
Students on the autism spectrum enjoy playing games, as this provides a safe environment [51].
People with ASD experience difficulties with developing social skills [52], which leads to social isolation [53].
The delay of fine motor skills development causes difficulties with interaction [54].
People with ASD have difficulties when generalizing skills to real-world contexts [55].
People with ASD find real social interactions to be stressful and intimidating because they are unpredictable [56] as well as being initially frightening, challenging, and even undesirable.
People with ASD tend to be more susceptible to experiencing depression and frustration [57].
The patterns of restricted or repetitive behaviors that characterize people with ASD leads to problems with adapting to novel environments [1].
People with ASD show persistent deficits in social communication and social interaction across multiple contexts [1].
People with ASD exhibit deficits in social–emotional reciprocity [1].
People with ASD exhibit deficits in nonverbal communicative behaviors used for social interaction [1].
People with ASD exhibit deficits in developing, maintaining, and understanding relationships [1].
People with ASD exhibit restricted, repetitive patterns of behavior, interests, or activities [1].
People with ASD exhibit stereotyped or repetitive motor movements, use of objects, or speech [1].
People with ASD insist on consistency, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior [1].
People with ASD have highly restricted, fixated interests that are abnormal in intensity or focus [1].
People with ASD exhibit hyper- or hypo-reactivity to sensory input or an unusual interest in sensory aspects of the environment [1].

4.1.2. Collection and Selection of UX Factors

Authors have defined factors/attributes with the end goal of evaluating the usability and user experience of a specific product. Some examples of this include the following:

- Usability:
  - Aspects [5]: effectiveness, efficiency, and satisfaction.
  - Attributes [6]: learnability, efficiency, memorability, errors, and satisfaction.
- User experience:
  - Facets [7]: dependability, usability, playability, accessibility, plasticity, communicability, cross-cultural capacity, emotionality, desirableness, usefulness, and findability.
  - Factors [8]: useful, usable, desirable, findable, credible, accessible, and valuable.

The selection of such factors/attributes should be dependent on the nature and characteristics of the product and scope of the investigation. Considering the focus of this investigation, we selected the seven UX factors proposed by Morville [8], who states that the Useful, Usable, Desirable, Findable, Accessible, Credible, and Valuable factors contribute to a successful user experience. The definitions for each of these factors are presented in Table 2 below.

Table 2. Morville UX Factors.

Factors Name	Definition
Useful	Content should be original and useful and fulfill a need.
Usable	Systems should be familiar, simple, easy to understand, and easy to use. The process of learning how to use a system should be as fast and simple as possible.
Desirable	Design elements such as images, identities, brands, and other features are used to evoke emotions and appreciation. The visual aesthetics of the product, service, and/or system should be attractive and easy to understand.
Findable	Information should be findable and easy to navigate. Users should be able to quickly find solutions to any problem encountered. The navigational structure should be set up in a way that makes sense.
Accessible	The product or service should be designed so that even users with disabilities can have the same user experience as others.
Credible	Products and services should be trustworthy and comply with their designed function.
Valuable	A product should deliver value to the business that created it and to the user who buys or uses it.

4.1.3. Match between Identified Characteristics and UX Factors

After the compilation of the information described above, matching was employed. We matched the characteristics, difficulties, and affinities of people with ASD to the seven factors raised by Morville [8] to use these elements to specifically define what the user experience means for people with ASD.

To carry out the matching procedure, we performed the following steps: (i) for each of the seven UX factors, one or more characteristics, difficulties, and/or affinities of the users were associated, and (ii) a new specified UX factor was drafted to make it more specific to the selected characteristics. Table 3 presents an example of this mapping procedure, where we present characteristics that match the definition for Morville's "findable" factor, and then we define an adapted UX factor for people with ASD. Appendix A Table A1 presents the matching results for all seven of Morville's UX factors.

Table 3. Sample of UX Factors Specified for ASD.

Morville UX Factor	Characteristics/Difficulties/Affinities of People with ASD	UX Factor for People with ASD
Findable	• Stereotyped or repetitive motor movements, use of objects, or speech [1]. • Insistence on sameness, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior [1]. • A tendency toward visual and structured thinking [50]. • Patterns of restricted or repetitive behaviors that characterize people with ASD leading to problems with adapting to novel environments [1].	• Information and navigational setup should be structured and consistent to adapt to the inflexible and structured thinking of users with ASD. • The users should be able to quickly find information and solutions to any problem to facilitate adaptation to novel environments and avoid frustration.

4.1.4. Preliminary Proposal of UX Factors for People with ASD Based on Characteristics

After collecting, analyzing, and refining the information described in the above sections, eight specific UX factors for systems used by people with ASD are proposed. Table 4 presents a preliminary definition for each of the factors.

Table 4. Set 1: Preliminary Definitions of UX Factors Based on ASD User Characteristics.

UX Factor	Definition
Safe	The system should provide a safe environment to help users fulfill their needs. Design elements should evoke emotions and appreciation, ensuring a safe and trustworthy environment through technology.
Predictable	The system and its content should be predictable and not stressful or intimidating to create a trustworthy context for users.
Generalizable	The system, including its aesthetics, audio, and inputs, should be familiar enough and similar enough to real life to facilitate interpretation and the generalization of skills.
Structured	Content, visuals, and navigational layouts should be structured, consistent, and controlled to appeal to the structured and visual thinking of the users.
Valuable	The system should have perceived value for its users.
Easy	The system should be designed to be easy to use, enjoyable, and engaging for users with and without ASD.
Sociable	The system should consider deficits in social interaction when including any social elements in its design (providing tools to facilitate social interactions when needed).
Frustration Free	The system should prevent frustration in users through its design and error management so users can quickly adapt to novel environments and find information and solutions to any problem.

4.2. Step 2: Guidelines from the Literature

In a second step, as shown in Figure 2, after a review of the literature, we identified and compiled design guidelines and/or recommendations defined by authors based on the characteristics of people with ASD in technological and nontechnological contexts.

Figure 2. Process for Defining UX Factors Based on ASD Guidelines and Recommendations.

We followed a three-step process to define UX factors for people with ASD based on ASD guidelines and recommendations: (1) the compilation of articles that propose and/or use design guides and/or recommendations, (2) grouping and categorizing design guidelines and/or recommendations based on their similarities, and (3) the proposal of a second set of UX factors for people with ASD.

4.2.1. Identifying Guidelines in the Literature

After a recent literature review, a total of 16 articles were found to focus on proposing and/or using guidelines to design systems or places frequented by people with ASD. From these articles, 290 design guidelines or recommendations were identified and are presented in Table A2 under the names or identifiers given by the authors. For studies [42,43], only the number of guidelines is shown since the authors do not provide short identifiers for them.

The studies present varying amounts of design guidelines and/or recommendations, which are generally focused on different aspects to consider when designing systems or interventions for people with ASD. These differences between quantities and categories may be attributable to this being a little explored field, and there is no consensus or established definition of aspects to consider when working with people with ASD, which supports the need to specify and agree on these aspects.

4.2.2. Grouping and Categorization

Following the results given in Table A2, the 290 design guidelines or recommendations found were grouped and categorized according to similarities in their definitions. In Table A3, the design guidelines or recommendations are categorized into 10 categories, which are divided into 32 subcategories of aspects to be consider when designing systems for people with ASD. For each of the subcategories, we cite a representative phrase for the group as an example selected from a study that considers this guideline or recommendation. An example of the grouping and categorization of guidelines and recommendations is given in Table 5. The full process employed is documented in Table A3.

Table 5. ASD Guideline and Recommendation Categorization.

Category	Subcategory	Definition	Sources
Structure, Repeatability, and Predictability	Structure	"Children with autism thrive in a structured environment. Establish a routine and keep it as consistent as possible." [43]	[3,39,42,43,45]
	Repetition	"Children with autism generally enjoy repetition and may engage in repetitive activity to the detriment of other activities." [42]	[34,38,41–43,46,48]
	Consistency	"The system should use clear and consistent language so that users do not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions in the design for consistency." [40]	[34,38–40,43,45,46]
	Predictability	"When working with people with autism spectrum disorder, it must be ensured that we provide a structured and predictable learning environment, since people with ASD have restricted and repetitive patterns of behavior, interests or verbal and non-verbal activities." [3]	[3,34,38,39,42,43,46]
	Control	"Software solutions designed for users with ASD must ensure that they always have control (e.g., pause, restart) over the computer processing." [46]	[42,43,46]

As shown in Table A3, multiple studies establish design guidelines and/or recommendations for aspects to consider when designing systems for people with ASD. Aspects such as personalization, customization, and graphics are most frequently considered in design guidelines and/or recommendations proposed in studies given the diverse characteristics and affinities that users may have. In contrast, aspects such as a simple and concise memory load, control, and recovery are the least explored by research.

4.2.3. Preliminary Proposal of UX Factors for People with ASD Based on Design Guidelines

Considering the grouping of similar concepts described in Table A3, a second set of refined preliminary UX factors for people with ASD based on design guidelines and/or recommendations is established. This refined proposal considers a total of eight UX factors, establishing an identifying name and specific definition, as shown in Table 6.

As the objective of our research is to establish UX factors that allow us to evaluate software systems designed for people with ASD, we eliminate the category "External Agents" presented in Table A3 because it focuses on aspects external to software.

Table 6. Set 2: Preliminary Proposal of UX Factors Based on ASD Guidelines and Recommendations.

UX Factor	Definition
Engagement	Systems designed for people with ASD must engage users through feedback, rewards, and motivational elements.
Tasks and Interaction	Systems for people with ASD should include tasks and interactions that consider the characteristics, affinities, and needs of the users. Tasks must evolve; be designed in a simple and concise way; have a single, clear, and explicit objective; and keep the memory load low.
Generalizable	Systems for people with ASD should be familiar to users. Known and/or previously learned elements must be included to facilitate their interpretation and thus their generalization to daily life.
Customization and Personalization	Systems for people with ASD must be customizable and easily personalized. The system must adapt to the characteristics of the users while also allowing users and tutors to flexibly personalize the characteristics of the system.
Senses	Systems for people with ASD must consider the senses of the users. The eventual rejection of visual, auditory, and physical stimulation should be considered.
Structure, Repeatability, and Predictability	Systems for people with ASD should be structured and predictable and allow for the repetition of actions.
Attention and Timing	Systems for people with ASD must retain users' attention, manage timing appropriately, and avoid the involvement of distracting elements during interaction.
Error Management	There must be error management in systems for people with ASD. Systems must facilitate the prevention and recognition of and recover from eventual errors that may occur during interactions with users by communicating clearly and accurately through a simple language that is familiar to users.

5. A Set of UX Factors for People with ASD

Given the definitions established in set 1 (Table 4) and set 2 (Table 6), the preliminary UX factors were merged to formulate a proposal of UX factors for people with ASD, as shown in Figure 3. In this proposal, a total of nine UX factors are defined: Engaging, Predictable, Structured, Interactive, Generalizable, Customizable, Sense-aware, Attention retaining, and Frustration Free. Definitions for each of the proposed UX factors are presented in Table 7.

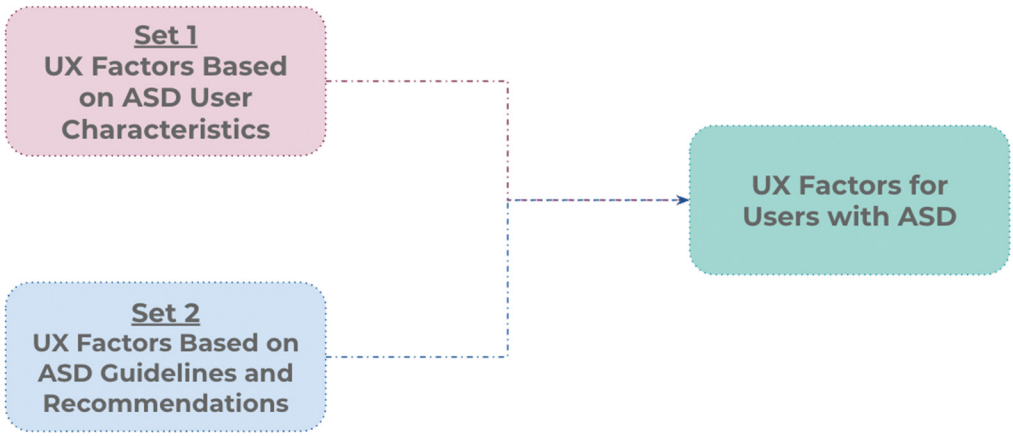

Figure 3. Process of Defining Final UX Factors for Users with ASD.

Table 7. UX Factors for Users with ASD.

UX Factor	Definition
Engaging	Systems for people with ASD must engage users. To encourage engagement from users, the system must provide: (1) feedback in a constant, concrete, and accurate way regarding the user's actions, (2) rewards in response to good performance, and (3) motivating elements such as the use of game elements and visual or auditory elements that are attractive.
Predictable	Systems for people with ASD must provide a predictable environment. Allowing the repetition of actions and providing a high level of control over the system in a friendly and safe environment will help generate a predictable and reliable context to interact with.
Structured	Systems for people with ASD must be structured. Providing clearly structured, simple, and consistent graphic, navigation, and interactive elements during system use will generate a safe and reliable environment for users.
Interactive	Systems for people with ASD must generate interactions based on the characteristics, affinities, and needs of users and based on their difficulties with social interactions. Tasks must evolve and increase in difficulty based on learning and adaptation pace. The proposed tasks must be designed in a simple and concise way and have a single objective that is clear and explicit. Memory load should be minimized during all interactions with the system. Instructions with adequate and concise language should be presented given an affinity for visual learning among people with ASD.
Generalizable	Systems for people with ASD should be familiar to users. They must have visual elements, audio, and known and/or previously learned inputs to facilitate interpretation and thus generalization to daily life.
Customizable	Systems for people with ASD must be customizable. The system must adapt to the characteristics, affinities, and needs of users. Users and tutors should be allowed to flexibly personalize aspects of the system, including colors, textures, font sizes, and volume levels, among other aspects, so that the system is easy to use, pleasant, and attractive for users.
Sense-aware	Systems for people with ASD should consider the users' senses. The system must provide a simple, readable, clear, and understandable layout with physically spaced elements in its interfaces. Pleasant graphics should be provided for users, prioritizing a minimalistic aesthetic and avoiding the use of distracting or anxiety-provoking colors. Use a familiar and simple language for users, and prioritize the use of icons/symbols. Sensory overload should be avoided, so do not saturate sites with information, images, audio, or text. When using sounds to interact with users, ensure they are clear, simple, functional, and nondisruptive. Potentially reduced motor skills should be considered through the use of touch screens, non-touch interfaces, and hybrid options.
Attention Retaining	Systems for people with ASD must retain the attention of users by managing timing appropriately. The timing of transitions should be minimized, and users should be given enough time to interact with the system. The system should have elements that help with attention retention, such as dynamic stimuli, while not including elements that could be distracting or cause sensory overload.
Frustration Free	Systems for people with ASD should prevent the frustration of users during interactions. Error management should be considered to prevent potential errors, easily recognize errors, and facilitate recovery from any unwanted state. It is important to communicate any errors clearly and accurately using simple language that is familiar to users.

In this set of UX factors, concepts such as "Engaging" or "Interactive" are included, which can be applied in contexts where learning is the focus of research. We believe that each of the proposed factors contributes to evaluating systems designed for people with ASD in general contexts and is not limited to learning settings. The nine UX factors established for people with ASD can be used to identify the most important or interesting areas that can be developed or addressed when designing systems for people with ASD. Defining these factors helps elucidate what UX implies and means and what is essential for ASD users. Additionally, we believe that these nine UX factors can contribute to adapting or creating new UX evaluation instruments and/or methods, which could contribute to the improvement of UX for systems designed for people with ASD.

6. Conclusions

Several studies have evaluated the UX and/or usability of systems for people with ASD. However, as evidenced in previous studies [2] and given the present investigation, empirical evidence and sufficient details are not presented to help us evaluate UX in systems for people with ASD. Additionally, it should be noted that no research has discussed UX factors of systems for people with ASD. Given the characteristics, affinities, and needs of people with ASD, we believe that it is pertinent to explore and specify UX factors that help evaluate systems designed for these users.

Given that there is no consensus on how to design specific UX factors regardless of the contexts in question, we used two means of search and information capture to establish guidance on UX factors for people with ASD.

The first approach focused on compiling the characteristics, affinities, and needs of people with ASD found in the literature as well as existing UX models. Since the UX models found do not consider the characteristics of people with ASD, we considered Morville's honeycomb [8] model, and we tailored it to the characteristics, affinities, and needs of people with ASD. In this way, a first set of UX factors for use in systems designed for people with ASD was established.

The second approach involved compiling design guidelines and/or recommendations from the literature focused on technological systems for people with ASD. The design guidelines and/or recommendations found were grouped and classified to establish a new set of UX factors specific to systems designed for people with ASD.

We believe that these two approaches helped us analyze different perspectives on how the creation of specific UX factors should be carried out. An established UX factor creation methodology would have helped further support our research. We believe that the methods adopted helped us establish a good proposal on specific UX factors for systems designed for people with ASD.

In combining our preliminary UX factor proposals, we define a final set of UX factors for people with ASD that includes nine UX factors: Engaging, Predictable, Structured, Interactive, Generalizable, Customizable, Sense-aware, Attention Retaining, and Frustration Free.

These nine UX factors lead to a new UX model for people with ASD. The UX factors can be used to design appropriate systems for users with ASD. We believe that this set of UX factors will provide a theoretical basis for the possible adaptation or creation of evaluation instruments, methods, and methodologies and for the development of recommendations and design guidelines. These factors will help complete and enable future research that seeks to evaluate systems for people with ASD.

We believe that each of the established UX factors complements the others and that systems designed for people with ASD that comply with these factors will provide added value and will increase the satisfaction of users who interact with this system.

In future work, we intend to propose a methodology for evaluating the UX of people with ASD that uses adapted evaluation instruments and methods for users with ASD based on the new nine-factor UX model.

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Appendix A

Table A1. UX Factors Specified for ASD.

Morville UX Factor	Characteristics/Difficulties/Affinities for People with ASD	UX Factors for People with ASD
Useful	• Specifically, students on the autism spectrum enjoy playing games, as this provides a safe environment [51]. • People with ASD find real social interactions to be stressful and intimidating because they are unpredictable [56], initially frightening, challenging, and even undesirable. • People with ASD experience difficulties in developing social skills [52], which leads to social isolation [53].	• The system should provide a safe environment to help users fulfill their needs. • The content should be predictable and should not be stressful or intimidating (frightening, challenging, and undesirable) when socializing, thus facilitating social interaction needs.
Usable	• People with ASD have difficulties when generalizing skills to real-world contexts [55]. • People with ASD tend to be more susceptible to experiencing depression and frustration [57]. • People with ASD find real social interactions to be stressful and intimidating because they are unpredictable [56], initially frightening, challenging, and even undesirable. • People with ASD have a tendency to engage in visual and structured thinking [50]. • People with ASD exhibit hyper- or hypo-reactivity to sensory input or an unusual interest in sensory aspects of the environment [1].	• The system should be familiar enough and similar enough to real life to facilitate generalizing skills. • The system should be simple so it is easy to understand and does not cause frustration or demotivation. • The system should be predictable so that it is not stressful or intimidating. • The system should be easy to use by focusing on providing visual and structured elements. • Learning through interaction with system should not be frightening. • Elements of the system should be measured/controlled to not cause hyper- or hypo-reactivity to sensory inputs, such as visual, auditory, and tactile inputs.
Desirable	• People with autism spectrum disorder (ASD) tend to enjoy themselves and be engaged when interacting with computers, as these interactions occur in a safe and trustworthy environment [2]. • Specifically, students on the autism spectrum enjoy playing games, as this provides a safe environment [51]. • People with ASD have a tendency to engage in visual and structured thinking [50]. • People with ASD have difficulties when generalizing skills to real-world contexts [55].	• Design elements should evoke emotions and appreciation, ensuring a safe and trustworthy environment through technology. • Visual aesthetics should be attractive and focused to appeal to the structured and visual thinking of users ASD. • Visual aesthetics, audio, and touch inputs should reflect real life to facilitate interpretation and the generalization of skills.

Table A1. *Cont.*

Morville UX Factor	Characteristics/Difficulties/Affinities for People with ASD	UX Factors for People with ASD
Findable	• People with ASD exhibit stereotyped or repetitive motor movements, use of objects, or speech [1]. • People with ASD insist on sameness, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior [1]. • People with ASD have a tendency to engage in visual and structured thinking [50]. • Patterns of restricted or repetitive behaviors that characterize people with ASD lead to problems with adapting to novel environments [1].	• Information and navigational setup should be structured and consistent to adapt to the inflexible and structured thinking of users with ASD. • Users should be able to quickly find information and solutions to any problem to facilitate adaptation to novel environments and prevent frustration.
Accessible	• Delays in the development of fine motor skills create difficulty with interactions [54]. • People with ASD show persistent deficits in social communication and interaction across multiple contexts [1]. • People with ASD exhibit deficits in social–emotional reciprocity [1]. • People with ASD exhibit deficits in nonverbal communicative behaviors used for social interaction [1]. • People with ASD exhibit deficits in developing, maintaining, and understanding relationships [1].	• The system should be designed to be easy to use, enjoyable, and engaging for users with and without ASD. • The system should consider deficits in social interaction when including any social elements in its design. • The system should consider deficits in fine motor skills during interactions through any input device.
Credible	• People with ASD find real social interactions to be stressful and intimidating because they are unpredictable [56], initially frightening, challenging, and even undesirable. • People with ASD tend to be more susceptible to experiencing depression and frustration [57].	• The system should provide a nonstressful, nonfrustrating, and predictable environment to create a trustworthy context for users. • The system should comply with skills learning functions.
Valuable	• People with ASD have difficulties when generalizing skills to real-world contexts [55].	• The system should have perceived value for creators and real-life value for skills learning through generalization to real-world contexts.

Table A2. ASD Guidelines and Recommendations Provided in the Literature.

Title	Guidelines
Design Guidelines for Serious Games Targeted to People with Autism [36].	Feedback
	Customization and personalization
	Graphical interface
	Increasing game difficulty
	Repetition
	Motivators
	Participatory design
Nature as a Healer for Autistic Children [48].	Visual principle as a therapeutic tool
	Design elements as a therapeutic tool
	Physical landscape feature as a therapeutic tool
	Landscape resources and materials as a therapeutic tool
	Design guidelines
Designing and Evaluating Touchless Playful Interaction for ASD Children [34].	General guidelines
	Goal-specific guidelines: Motor skills
	Goal-specific guidelines: Cognitive skills
	Goal-specific guidelines: Social skills
Design Considerations for the Autism Spectrum Disorder-Friendly Key Stage 1 Classroom [49].	Threshold and entrance
	Cloakroom provision
	Sight lines entering the classroom
	Visual timetable
	High-level glazing
	Volumetric expression
	Control
	Access to classroom external play
	Access to school playground
	Quiet room
	Toilet provision
	Kitchen
	Floor area
	Storage
	Computer provision
	Workstations
Designing Visualizations to Facilitate Multisyllabic Speech with Children with Autism and Speech Delays [44].	Minimize delay to interaction
	Real-time is fun
	Child customization
	Dynamic computer correction
	Robust microphone setup
	Competence of the child
	Physical interaction
Assessing the Target' Size and Drag Distance in Mobile Applications for Users with Autism [35].	Minimum pixel size

Table A2. *Cont.*

Title	Guidelines
Empowering Children with ASD and Their Parents: Design of a Serious Game for Anxiety and Stress Reduction [38].	Customizability
	Evolving tasks
	Unique goal
	Instructions
	Reward
	Repeatability
	Transitions
	Minimalistic graphics
	Clear audio
	Dynamic stimuli
	Serendipity
	Sound and music
	Background story
	Language and text
	Actions and goals
	Simplicity
	Scoring
Towards a Serious Games Design Framework for People with Intellectual Disability or Autism Spectrum Disorder [37].	Pedagogy
	Learning content and game mechanics
	Evaluation
Development of the AASPIRE Web Accessibility Guidelines for Autistic Web Users [45].	Physical accessibility
	Intellectual accessibility
	Social accessibility
AutismGuide: Usability Guidelines to Design Software Solutions for Users with Autism Spectrum Disorder [46].	General usability principles
	Nonfunctional requirements
	Functional requirements for caregivers/partners
	Adaptability
	Guidance
	Workload
	Compatibility
	Explicit control
	Significance of codes
	Error management
	Consistency
Towards Developing Digital Interventions Supporting Empathic Ability for Children with Autism Spectrum Disorder [39].	Graphical layout
	Navigation and structure
	Language
	Interaction

Table A2. *Cont.*

Title	Guidelines
Creating Individualized Computer-Assisted Instruction for Students with Autism Using Multimedia Authoring Software [41].	Learning styles of individual students
	Independent responding
	Social interaction
	Responsivity
	Age appropriateness
	Overlearning
	Natural environment
	Generalization
	Communication attempts
	Student choice of stimulus materials
	Cognitive ability
	Task variation
	Over-selectivity
	Vary the reinforcers
	Multiple cues
	Prompts
	Maximal use of technology
	Data collection as a design feature
Learning Styles of Autistic Children [43].	The authors do not detail specific categories for 18 guidelines and/or recommendations
Understanding Natural Language [42].	The authors do not detail specific categories for eight guidelines and/or recommendations
Heuristics to Evaluate Interactive Systems for Children with Autism Spectrum Disorder (ASD) [40].	Visibility of system status
	Match between system and the real world
	Consistency and standards
	Recognition rather than recall
	Aesthetic and minimalist design—minimize distraction and keep design simple
	User control and freedom
	Error prevention
	Flexibility and efficiency of use
	Help users recognize, diagnose, and recover from errors
	Help and documentation
	Personalization of screen items
	User interface screens of the system
	Responsiveness of the system
	Track user activities, monitor performance, and repeat activity
	Use of multimodalities for communication
Technology-Based Social Skills Learning for People with Autism Spectrum Disorder [3].	Structured and predictable learning environment
	Generalization to daily life
	Learning dynamics: individual and collaborative
	Engagement through activity cycles and game elements
	Error managing
	Mixed activities
	No-touch and hybrid interfaces

Table A3. ASD Guideline and Recommendation Categorization.

Category	Subcategory	Definition	Sources
Engagement	Feedback	"Software solution designed for users with ASD must (. . .) provide immediate feedback on the user's actions (the response time must be as short as possible)." [46]	[3,36,40,43,46,48]
	Rewards	"Offering a reward after a good performance, increases the child's motivation, engagement and implicitly improves skills." [38]	[3,34,38]
	Motivation	"Motivation encourages users to achieve objectives and develop expected behaviors. This motivation can be extrinsic and intrinsic." [3]	[3,34,36,37,41]
Task Interaction	Task Design	"Software solutions designed for users with ASD must take account of their various characteristics (habits, skills, age, expectations, etc.) and adapt the tasks, navigation, layout, etc., accordingly." [46]	[34,38,41,43,46]
	Evolution	"Increasing levels of motor or cognitive complexity should be incorporated in the game." [38]	[3,34,36–38,44]
	Simple and Concise	"Make content as concise as possible without sacrificing precision and specificity, to reduce cognitive burden." [45]	[45]
	Instructions	"The software should speak directions to the student in a clear and direct manner." [41]	[34,38–41,45,46]
	Memory Load	"Minimise 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 screen to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate." [40]	[40]
	Goal	"There should be one unique explicit goal to reach within a gaming session." [38]	[34,37,38]
Generalizable	Generalizable	"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." [40]	[3,40,41,45]
Personalization and Customization	Personalization	"The system should allow personalisation of screen items based on needs, abilities and preferences of an individual child. Screen items should be large enough for children to read and interact with. It should also allow them to change various settings of system background, font, colour, screen size and others." [40]	[34,36–38,40,44–46]
	Customization	"Software solutions designed for users with ASD must react to the context and these users' needs and preferences." [46]	[3,34,38,40,41,43–46,48]
Senses	Layout	"Use the simplest interface possible for ease of understanding." [45]	[35,39,41–43,45,46,48,49]
	Graphics	"Graphics should be aesthetically pleasing, but always functional. Irrelevant elements might form a distraction and can lead to loss of attention. Too many visual or colors might trigger anxiety as it might be difficult for the child to interpret individual elements." [38]	[34,36,38,39,41,43,45,46,48]
	Language	"Any language and text present in the game should be free from figures of speech and as clear as possible" [38]	[38,39,43,45,46]
	Workload	"Software solutions designed for users with ASD must promote their perception, concentration, attention, memory, etc. They must therefore (. . .) avoid users being exposed to large numbers of functionalities, images, animations, etc., at any one time" [46]	[37,40,43,46,49]
	Audio	"Children with ASD can be sensitive to audio stimuli, which can create extra stress. Sound or music can be used to provide feedback on actions, to complement a visual reward or during a transition phase in the game." [38]	[34,38,41–43,46]

Table A3. *Cont.*

Category	Subcategory	Definition	Sources
Senses	Physical	"Children want to touch everything. Touch is an easy-to-understand interaction. Therefore, design systems that not only respond to touch, but provide meaningful feedback for those interaction" [44]	[3,34,42,44,46,48]
Structure, Repeatability, and Predictability	Structured	"Children with autism thrive in a structured environment. Establish a routine and keep it as consistent as possible." [43]	[3,39,42,43,45]
	Repetition	"Children with autism generally enjoy repetition and may engage in repetitive activity to the detriment of other activities." [42]	[34,38,41–43,46,48]
	Consistency	"The system should use clear and consistent language so that users do not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions in the design for consistency." [40]	[34,38–40,43,45,46]
	Predictability	"When working with people with autism spectrum disorder, it must be ensured that we provide a structured and predictable learning environment, since people with ASD have restricted and repetitive patterns of behavior, interests or verbal and non-verbal activities." [3]	[3,34,38,39,42,43,46]
	Control	"Software solutions designed for users with ASD must ensure that they always have control (e.g., pause, restart) over the computer processing." [46]	[42,43,46]
Attention and Timing	Attention Retention	"Providing animations or music helps to retain the child's attention. If there are no visual or auditive stimuli, the child might lose his/her attention. A prolonged static visual, on the other hand, might trigger unwanted behavior, such as stereotyped movements or motor rigidity, e.g., gazing at a static image on the screen." [38]	[34,38,41,42,44]
	Distraction	"The time of restarting a session or switching from one level to the next one must be minimized, to reduce the risk of a child's loss of concentration during the transition." [34]	[34,38,40,42,46]
	Timing	"When designing software for children, ensure that when the child wants to engage, and the software is ready to respond and delays are minimized." [44]	[38,40,41,43,44]
External Agents	Location	"Select a location with the least amount of distractions possible. high-pitched or humming noise, adjacent traffic and noise from air conditioning compressors can be overwhelming." [48]	[34,48,49]
	People	"It is important to include special education teachers and professionals in the design phase of a SG. They can define the requirements, goals and learning objectives of the game." [37]	[36,37,41,46]
	Hardware	"Software solutions designed for users with ASD must . . . have a long lifespan (robust hardware, without frequent replacement need, etc.) and high availability (independent of Wi-Fi and available via Web, tablet and laptop)" [46]	[40,41,46]
Error Management	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." [40]	[3,40,42,45,46]
	Recognition	"(. . .) provide good-quality error messages (clear, multimedia message: video, audio, animation) and avoid indicating success or failure solely by means of a colour or a facial expression (frown, smile, etc.)" [46]	[40,41,46]
	Recovery	"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. The system should allow users to move from one part to another and provide the facility to repetitively perform activities." [40]	[40,46]

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Article

A Methodology to Evaluate User Experience for People with Autism Spectrum Disorder

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Abstract: People with Autism Spectrum Disorder (ASD) have an affinity for technology, which is why multiple studies have implemented different technological proposals focused on the development of skills in people with ASD. Studies have evaluated the user experience (UX) and/or usability of their technological proposals through different evaluation methods, so they can be friendly and usable for users with ASD. However, the evaluation methods and instruments used do not consider the specific characteristics and needs of people with ASD, and furthermore, details are lacking in their implementations. To formalize the UX evaluation process, we propose a three-stage methodology to evaluate the UX in systems, products and services used by adults with ASD. The methodology considers in its processes, evaluation methods and instruments the characteristics of people with ASD so that, through the UX evaluation, the satisfaction and perception of these users about the system, product or service evaluated is improved. This proposal has been validated through the opinions of experts with knowledge in UX/Usability and ASD in two instances, which have contributed to specify, restructure, and improve the methodology.

Keywords: autism spectrum disorder (ASD); evaluation methodology; evaluation methods; user experience (UX); usability

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1. Introduction

Autism Spectrum Disorder (ASD) is a condition characterized by deficits in social communication and social interaction, as well as restricted repetitive patterns of behavior, interests, and activities [1]. Some characteristics that people with ASD can present are: a tendency towards visual and structured thinking [2], delay of fine motor skills development [3], difficulties when generalizing skills to real-world contexts [4], susceptibility to experiencing depression and frustration [5], exhibit of hyper- or hypo-reactivity to sensory input or an unusual interest in sensory aspects of the environment [1], and that they prefer to use technology as it provides a safe and trustworthy environment [6].

It is important that the process to evaluate the user experience (UX), as well as the evaluation methods and instruments, are selected and adapted considering the specific characteristics of users with ASD, to ensure a positive and rewarding experience when interacting with systems, products or services.

Multiple studies have looked on how to evaluate UX in systems, products, or services used by people with ASD, however most of these studies do not present sufficient details of the evaluations performed and show a lack of empirical evidence [6]. Investigations have proposed different ways to evaluate UX and usability in their proposals, through different evaluation methods, which are defined as "a procedure composed of a series of well-defined activities for the collection of data related to the interaction of the end user (. . .)" [7], such as the system usability scale (SUS) [8] and heuristic evaluation [9], and instruments, which are a set of elements used by an evaluation method that can vary

depending on the application's context. Many of the evaluation methods and instruments used in the evaluations are not adapted to the characteristics and needs of people with ASD.

Considering this, the objective of this paper is to present a three-stage methodology to evaluate the user experience for people with ASD, as there is a need for a formal methodology to evaluate user experience that is built upon the needs and characteristics of users with ASD and provides proper guidelines and evaluation methods for them.

This methodology was developed by researching the characteristics of the users through a systematic literature review [6], proposing a set of adapted UX factors [10], selecting evaluation methods suitable for the needs of users with ASD, and defining a logical step-by-step process to select evaluation methods to execute, plan the experiments, select evaluators and participants, carry out the selected methods, and perform qualitative and quantitative analysis, which results in a detailed report on the UX of the system, product or service evaluated.

A preliminary version of the methodology was published in 2021 [11], which was reviewed and validated through the opinion of three experts in UX and later via an expert judgement validation by 22 experts with knowledge on UX, ASD and/or both, which resulted in the proposal presented in this paper.

This document is organized as follows: Section 2 presents the theoretical background; Section 3 describes relevant related work; Section 4 shows the process to create the methodology; Section 5 presents the UX evaluation methodology for people with ASD; Section 6 presents the validation process; and Section 7 presents our conclusions and future work.

2. Theoretical Background

Below are brief descriptions of ASD, UX, and UX models, which are relevant for this investigation.

2.1. Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a condition characterized by repetitive patterns, difficulties with social interaction, and communication, as defined in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM 5) [1].

People with ASD may or may not present secondary symptoms, such as intellectual disability, lack of verbal language [1], a tendency towards visual and structured thinking [2], delay of fine motor skills development [3], difficulties when generalizing skills to real-world contexts [4], susceptibility to experiencing depression and frustration [5], and hyper- or hypo-reactivity to sensory input [1].

The DSM 5 establishes three categories of severity for ASD [1] based on the degree of support that the person needs, which varies from level 1 "Requires support" to level 3 "Requires very substantial support".

2.2. User Experience

ISO 9241-210 [12] defines user experience (UX) as "user's perceptions and responses that result from the use and/or anticipated use of a system, product or service". Additionally, the standard describes UX as "user perceptions and reactions, including user emotions, beliefs, preferences, perceptions, comfort, behaviors, and achievements that occur before, during, and after use". In other words, UX is understood as the internal and emotional state that people perceive before, during and after the interaction with a system, product, or service.

A part of UX is usability, which is defined by the ISO 9241-11 [13] standard as "the extent to which a system, product or service can be used by specific users to achieve specific goals with effectiveness, efficiency and satisfaction in a specific context of use". The concept of usability is related to the fulfillment of tasks and the satisfaction experienced by users, therefore, a higher degree of usability of a system, product, or service after user interaction leads to a better UX.

2.3. UX Evaluation Methods

A system or product can be evaluated using usability and/or UX evaluation methods. UX evaluation methods focus on detecting how the user feels about the interaction with the evaluated system or product [14]. On the other hand, usability evaluation methods are "a procedure composed of a series of well-defined activities for the collection of data related to the interaction of the end user with a software product and/or how a specific feature of this product of software contributes to achieving a certain degree of usability" [7]. Considering that the concept of user experience includes usability, we have chosen a set of UX evaluation methods that will help us effectively evaluate the UX and usability on systems, products or services used by people with ASD.

For our proposed methodology for evaluating systems, products, or services for people with ASD, we have selected evaluation methods under the following usability method classifications, as defined by Fernandez et al. [7]:

- *Inspections:* Reviews carried out by a group of evaluators using their expert judgement, where the participation of the users of the system or product is not included.
- *User Testing:* Users evaluate the product or system after interacting with it.

2.4. UX Factors for People with ASD

We have proposed a set of nine UX factors for systems used by people with ASD [10]: engaging, predictable, structured, interactive, generalizable, customizable, sense-aware, attention-retaining, and frustration-free. These nine UX factors have been considered when designing the tasks to be performed during the execution of the methodology, as well as when adapting instruments of the evaluation methods, such as the property checklist [15].

The nine UX factors have been created based on two approaches: (1) the characteristics, affinities and needs of people with ASD, and (2) the design guidelines and/or recommendations provided by studies on technological systems for people with ASD and/or interventions with these users.

This set of UX factors provides a theoretical basis for the adaptation or creation of evaluation methods, instruments, and methodologies that are focused on the user experience of people with ASD.

3. Related Work

To complement our findings in a previous systematic literature review [6], we have reviewed the literature that has emerged since the year 2019 in order to update the conclusions previously obtained regarding these related studies.

In recent times, the amount of research focused on developing systems and/or products for people with ASD has increased, which is possibly due to the growing interest in the affinity that people with ASD have with technology.

For systems and/or products developed for people with ASD to be friendly and usable, research has evaluated the satisfaction and/or perception of experts in the domain (psychologists, differential teachers, speech therapists), tutors and/or people with ASD, through different evaluation methods.

Studies have evaluated their proposals through the application of simplified and/or complete versions of the system usability scale (SUS) [8]. Some studies have modified the SUS scale (using simplified language, incorporating emoticons, or reducing the scale) when used with users with ASD [16,17]. Other studies have evaluated their proposals with experts in ASD and/or tutors of users with ASD, using the SUS scale in its complete [18–20] or reduced [21] version.

Other researchers have evaluated their proposals through sets of heuristics. Ramos-Aguiar and Álvarez-Rodríguez [22] state that they have evaluated their proposed application using Nielsen's heuristics [23]. Camargo et al. [24] mention having evaluated their mobile application with a heuristic evaluation using the Semiotic Interface sign Design and Evaluation (SIDE) framework [25].

Studies mention having evaluated their proposals using questionnaires. Susanti et al. [26] have evaluated the usability of their application through "direct observation" of users interacting with the application and the execution of the questionnaire proposed by Sehrish Khan [27] which aims to assess usability based on five categories: (1) ease of use, (2) learnability, (3) feedback and good error messages, (4) adequate help and documentation, and (5) appealing interface. Ghabban et al. [28] propose to evaluate their proposal through the creation of a new questionnaire model called M-UTUAT, which is based on seven attributes of the People at the Center of Mobile Application Development (PACMAD) model [29] and three factors of the Unified Theory of Acceptance and Use of Technology (UTAUT) model [30].

Multiple investigations have evaluated their proposals based on a set of evaluation methods. Ahmed et al. [31] mention having evaluated the usability of their proposal with the participation of people with ASD, through the application of three evaluation methods: (1) system usability scale (SUS) [8], (2) VR sensitivity scale and (3) a heuristic evaluation with the Nielsen set of heuristics [9]. Adiani et al. [32] state that they have evaluated their proposal with professionals, parents/caregivers and children with ASD through three evaluation methods: (1) system usability scale (SUS) [8], (2) Acceptability, Likely Effectiveness, Feasibility, and Appropriateness Questionnaire (ALFA-Q) [33] and (3) semi-structured Customer Discovery style interviews. Kim et al. [34] present a process based on four phases, where phase three aims to evaluate the usability of the proposed mobile application through a set of methods. In it, 18 people (9 people without ASD and 9 people with ASD) have been asked to participate in the execution of four evaluation methods sequentially. The evaluation methods used were: (1) Demographic Survey, (2) Think-Aloud Protocol [35], (3) Cognitive Walkthrough [36] and (4) system usability scale [8].

Studies in recent years show interest in evaluating the usability and UX in systems and/or products used by people with ASD. Evaluation methods, such as the system usability scale (SUS) [8] and the use of Nielsen's set of heuristics [23], are widely applied to find usability problems and provide an overview of the user's satisfaction of the system, product or service; however, we consider that the level of detail obtained is not sufficient to cover the particular needs that a user with ASD has when interacting with the evaluated system.

Methods, such as the Think-Aloud Protocol [35] and Cognitive Walkthrough [36], are useful to obtain information on the perception of the system directly from the final user of the system; however, by depending on the insights of people who may have communication deficits [1] and are susceptible to frustration [5], this method can deliver unreliable results for users with ASD, so it is necessary to have special considerations regarding its implementation, as well as the environment and the way in which we communicate with the user during the test.

In general, we believe that (1) the investigations must have a greater specification detail on the evaluations carried out, (2) the methods and instruments used must consider the characteristics and needs of people with ASD (example: there must be a set of heuristics focused on people with ASD), and also (3) we believe it is important to have the participation of UX/Usability experts, ASD experts, tutors and people with ASD.

4. Process to Create the Methodology

We have followed a seven-stage process to create the proposed methodology. It has been iterated twice in order to validate and refine the methodology (see Figure 1).

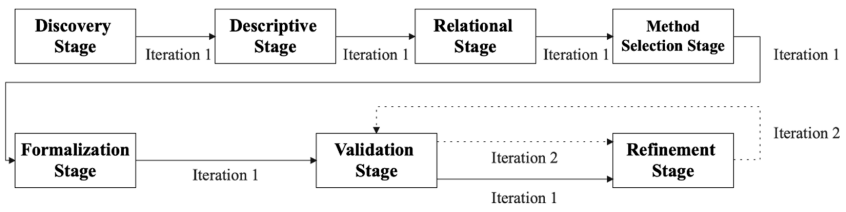

Figure 1. Overview of the process to create the methodology.

4.1. First Iteration

For the first iteration, all the stages have been executed (see Figure 1):

- *Discovery Stage:* We carried out a systematic literature review to know the impact that technology has on people with ASD and how UX/Usability has been evaluated in the proposed systems [6]. The studies indicate that they have evaluated their proposals through various evaluation methods, but these methods have not been particularized considering the characteristics of people with ASD [6].
- *Descriptive Stage:* We compiled the information found in the literature on the following topics: (1) characteristics, affinities and needs in people with ASD, (2) recommendations and comments from the authors on UX/Usability evaluations in systems, products or services used by people with ASD, and (3) UX attributes/facets/factors appropriate to the context of our research.
- *Relational Stage:* During the research carried out, a set of UX attributes/facets/factors focused on people with ASD has not been found, so by relating the information collected in the descriptive stage, we have proposed a set of nine UX factors for people with ASD [10].
- *Method Selection Stage:* We have selected a set of six evaluation methods suitable for people with ASD found in the discovery stage and on the website www.allaboutux.org [37]. Evaluation methods (special emphasis on user tests) based on individual and group questionnaires, focused on emotions and easy expressions, have been excluded.
- *Formalization Stage:* With the results obtained in the previous stages, we have formalized and published a preliminary proposal of the methodology to evaluate UX for people with ASD [11]. The proposal considers planning, execution, and result analysis stages.
- *Validation Stage:* We have validated the preliminary proposal of the methodology [11] through the opinions of three UX expert researchers. The experts have been asked about elements to add, modify, or eliminate to improve the methodology.
- *Refinement Stage:* We refined the preliminary proposal of the methodology [11] based on the results obtained in the previous stage. All comments and recommendations have been considered to improve the methodology.

4.2. Second Iteration

We have carried out a second iteration, which consisted of executing the validation and refinement stages again (see Figure 1).

- *Validation Stage:* An expert judgment evaluation was carried out with 22 experts with knowledge in UX/Usability, ASD and/or both. The expert judgment evaluation focused on gathering comments and suggestions of the experts about the stages, substages and the methodology in general (see Section 6).
- *Refinement Stage:* We have refined the methodology based on the comments and suggestions obtained in the expert judgment evaluation. The corresponding changes have been made after analyzing the comments and suggestions of the experts (see Section 6), resulting in the final version of the methodology proposed in Section 5.

5. A Methodology to Evaluate UX for People with ASD

Considering that literature do not present enough detail in the evaluations nor empirical evidence in their research, we believe that it is necessary to formalize the UX evaluation process in systems, products and services used by people with ASD. For this, we have created a three-stage methodology (see Figure 2). This methodology focuses on evaluating the UX of systems, products or services used by adults with ASD level 1, as defined in the DSM5 [1]. The methodology aims to maximize the amount of valuable information obtained about the UX of the system, product, or service, so that it can be used to improve the UX and therefore their use is satisfactory for people with ASD.

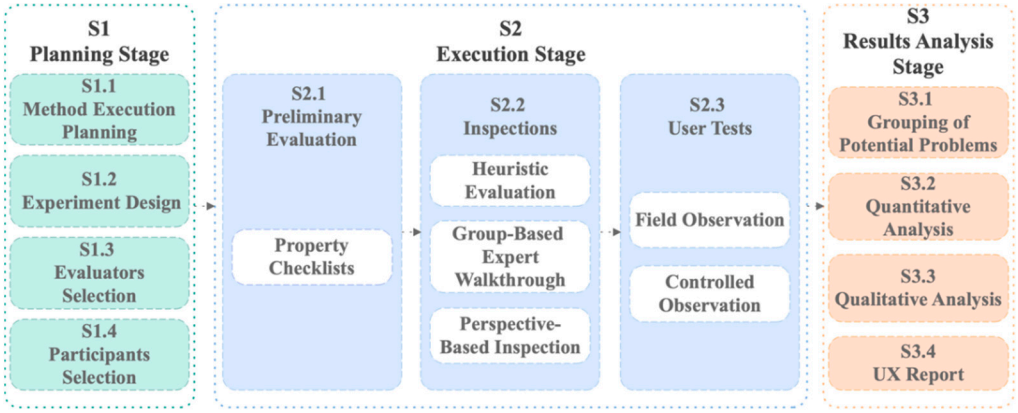

Figure 2. Stages of the UX evaluation methodology for people with ASD.

The methodology proposes three sequential stages, starting with the Planning Stage (S1), followed by the Execution Stage (S2) and ending with the Results Analysis Stage (S3). All stages and substages can be seen in Figure 2.

To facilitate the reading of the methodology the stages and substages are identified with unique IDs (such as S1, S2, S1.1), and their outputs with numerical icons (①, ②, ③), which are consistent with the diagram and tables presented in this document. Figure 3 presents a general description of the methodology and its stages, as well as the inputs and outputs of each of these.

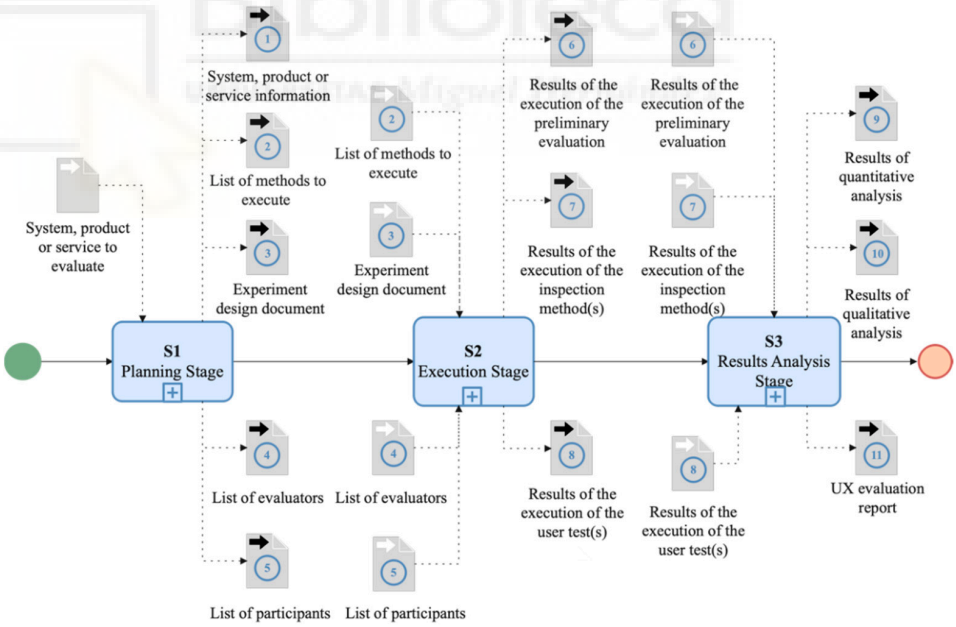

Figure 3. General description of the methodology.

When applying the methodology, consider:

- Carry out all the stages and substages proposed in the methodology. Consider that the execution stage has a set of substages, which in turn are made up of one or more evaluation methods.
- The methodology is flexible about which evaluation methods can be carried out in the execution stage. The choice of evaluation methods will depend on the criteria of the researchers, based on the objective of the evaluation, autonomy, and dependence of the participants, resources, and time available.

- Depending on the stage and substage, one or more documents will be required to start it. Similarly, executing each stage and substage will result in one or more documents.

Next, each of the stages and substages of the proposed methodology are presented in detail.

5.1. S1 Planning Stage

The purpose of the planning stage is to plan the UX evaluations to be carried out, as well as to search for UX/Usability experts, domain experts (professionals who work with people with ASD), participants and tutors. For more detail, see substages S1.1, S1.2, S1.3 and S1.4.

It is important to consider that before beginning this first stage, the system, product, or service to be evaluated, its characteristics and limitations, must be identified, as well as its target user.

As complementary material, Table A1 is presented in Appendix A. This table describes what is needed, what to do and what is obtained as an output when implementing this stage.

5.1.1. S1.1 Method Execution Planning

The purpose of the method execution planning substage is the selection and planning of the evaluation methods to be executed.

To determine and select the UX evaluation methods to apply to the system, product, or service to be evaluated, you must consider: (1) the objective and scope of the UX evaluation must be defined. The methods and activities must focus on the defined objective and scope; and (2) the resources and times available to carry out the UX evaluations must be established.

Depending on the objective of the evaluation, scope, resources, and available time, it is necessary to choose which methods to select. Based on the time and resources available, we propose the execution of the following sequences of evaluation methods:

- If you have enough time and resources, carry out each of the methods presented in the methodology (as shown in Figure 2).
- If you do not have enough time and resources are limited, execute only the following evaluation methods: property checklist, heuristic evaluation and field observation, since these are considered the baseline of the methodology.
- In any other case, select evaluation methods based on the complexity of each method. We suggest that:
    - Always execute the property checklists method.
    - Carry out at least one method of the inspections substage (S2.2) and the user tests substage (S2.3).
    - Depending on the time and resources available, one or more inspection methods can be carried out, selected according to the objective of the evaluation and the needs of the study. The order of the inspection methods of substage S2.2, from less to more complex, in terms of effort and resource requirements, is: heuristic evaluation, group-based expert walkthrough and perspective-based inspection.
    - Depending on the remaining time and resources, it is recommended to perform the "field observation" method if less time and resources are available, otherwise use the "controlled observation" method.
- If necessary, you can select and modify the selection of methods to use as you progress through the run stage.

Also consider selecting and/or adapting instruments of the evaluation methods to be carried out which are suitable for the needs of users with ASD. The instruments used in each of the selected methods must be particularized for people with ASD and the type of system, product, or service to be evaluated (e.g., select a set of heuristics for transactional systems for people with ASD).

As complementary material, Table A2 is presented in Appendix A. This table describes what is needed, what to do and what is obtained as an output when implementing this substage.

5.1.2. S1.2 Experiment Design

Once the evaluation objective, scope and methods that will be executed in the UX evaluation process are defined, a set of important aspects for the experiments to be carried out must be created and defined. These aspects are:

- Define the evaluation objective(s) for each method to be carried out.
- Define the expected results that will be obtained for each activity to be carried out in the UX evaluation methods.
- Define scenarios and tasks. Consider that:
  - In case of executing at least two evaluation methods that require scenarios and/or tasks, create universal scenarios and/or tasks, which can be used by multiple evaluation methods to reuse and optimize resources.
  - The design of tasks and scenarios must consider the characteristics and needs of people with ASD. The instruments to use in each evaluation method in this methodology should be adapted according to the recommendations described in this document, in order to maximize the value for people with ASD.
  - The scenarios and/or tasks created should focus on specific characteristics of the system, product, or service. Similarly, scenarios and/or tasks should be concise and clear.
  - In case of executing the "controlled observation" method, include an estimated time for completion, and the expected results of each task. These can be compared with the time that the participant took to perform the task, and the results obtained from it.
  - It is important to keep in mind that participants may require more time to understand the tasks to be performed, as well as more time to be prepared for the activity and to finish it. It can be frustrating for some users with ASD not to have enough time to complete the activities due to their strict routines [1].
- Define protocols (set of documents required for the execution of the evaluation methods). Consider:
  - *Confidentiality agreement:* In the case of the implementation of methods that require an audiovisual record of the actions of the participants, confidentiality agreements must be established. The purpose of the confidentiality agreement document is to inform the participant that their actions will be recorded, their identities will not be revealed, and that the purpose of the experiment is to evaluate the system, product, or service and not their abilities, skills, or knowledge.
  - *Preliminary questionnaire (demographic):* Experts and participants should be provided with a preliminary (demographic) questionnaire prior to performing the evaluation methods. The preliminary (demographic) questionnaire aims to identify the profiles and previous experiences that evaluators or participants may have with similar systems, products, or services.
  - *Perception questionnaire:* At the end of the execution of an evaluation method, the evaluators or participants must be provided with a system, product, or service perception questionnaire. The purpose of the questionnaire is to find out the different perceptions that the evaluators or participants have about the system, product or service evaluated and the tasks performed.
  - *Observer logs:* We recommend that UX leaders and/or researchers (in the role of observers) record what was observed during the method execution process in logs. Record potential problems, comments out loud from participants or evaluators, or information that UX leaders or researchers deem necessary in the logs.

- *List of tasks:* In the case of carrying out evaluation methods where a set of tasks is needed, create two documents with the list of tasks: (1) list of tasks for the evaluators or participants during the experiment, with the goal of providing a sequence of tasks to perform during interaction with the system, product or service; and (2) list of tasks for researchers and/or observers, which details the expected results and expected time for each proposed task.
- *List of potential problems:* Evaluators or observers should be asked, depending on the method to be carried out, to record the potential problems found through the evaluation (see the execution stage). It is expected that at least one definition, explanation or comment on the potential problem encountered will be provided. Once the potential problems have been identified, each evaluator and/or observer must assign a value of severity, frequency, and criticality to said problems, under the same evaluation scale (see Table A3).

- All documents delivered to participants must have clear and concise instructions, and if necessary, have visual support.
- All protocols presented must be established and documented in the Experiment Design document, which will be a necessary input to carry out each of the methods in the execution stage. The details and information provided to the evaluators or participants will depend on the evaluation method to be carried out, as established in the S2 execution stage.

As complementary material, Table A4 is presented in Appendix A. This table describes what is needed, what to do and what is obtained as an output when implementing this substage.

5.1.3. S1.3 Evaluators Selection

Search and select evaluators to participate in the execution of the UX evaluation methods proposed in the execution stage. We recommend that:

- The profiles of these evaluators must be: (1) experts in UX/Usability, (2) experts in the specific domain (professionals who work with people with ASD, for example psychologists, speech therapists and differential teachers), and/or (3) preferably experts with knowledge in both areas (UX/Usability and in the ASD domain).
- Have three to five evaluators [38] for each of the inspection methods to be carried out. Having the support of different professionals will help to include different points of view in the analysis and, eventually, find a greater diversity of potential UX problems.
- Have an expert who assumes the role of leader. This can be an expert with knowledge in both areas (UX/Usability and in the ASD domain) or a UX/Usability expert. The expert must accept this role and lead each of the evaluation methods to be carried out on the system, product, or service.
- In case of executing more than one inspection method, it is recommended to have different evaluators for each method to have different points of view and avoid possible biases.
- Evaluators who are experts in ASD or related areas will be responsible for guiding and educating the other evaluators on how to deal with users and their specific needs during user testing. Each user is different, and their needs may not be visible to an evaluator without ASD domain experience.

As complementary material, Table A5 is presented in Appendix A. This table describes what is needed, what to do and what is obtained as an output when implementing this substage.

5.1.4. S1.4 Participant Selection

Define and select the users who will be participants in the experiments to be carried out in substage S2.3 (User Tests), considering the target users of the system, product, or service to be evaluated. We recommend:

- Have three to five participants with ASD [38] for each of the evaluation methods of tests with users (controlled observation and field observation).
- If necessary, we recommend including tutors close to people with ASD, to create a safe environment for the participants. The tutors will take a guiding role for the participants with ASD, in case they are overwhelmed by the task or instructions given. Tutors must not intervene in the participant's interaction with the system, product, or service.
- In the case of executing the two test methods with users (controlled observation and field observation), it is recommended to use different participants for each method, to have different points of view and avoid possible biases.

As complementary material, Table A6 is presented in Appendix A. This table describes what is needed, what to do and what is obtained as an output when implementing this substage.

5.2. S2 Execution Stage

The execution stage has the purpose of executing previously selected methods to evaluate the user experience of systems, products, or services for people with ASD.

Before executing an evaluation method and considering the knowledge of the evaluator, it is recommended:

- For expert evaluators in UX and/or Usability: give them a brief induction on the ASD condition and its main characteristics.
- For expert evaluators in the ASD domain: give them a brief introduction to UX and the evaluation methods to be executed.
- Both groups of evaluators should be given a brief introduction about the system, product, or service to be evaluated, indicating its purpose, objective, and scope of the evaluation.
- The methods proposed in this methodology have been selected considering the characteristics of people with ASD, and they can be used to assess a variety of systems, products, or services for any type of user. Therefore, any necessary adjustments should be considered for their instruments or environment of execution.
- The proposed evaluation methods can be executed sequentially or in parallel. The order of execution will depend on the decisions made by the investigators.

As complementary material, Table A7 is presented in Appendix A. This table describes what is needed, what to do and what is obtained as an output when implementing this stage.

Next, the aspects to be considered when executing the proposed methods and instruments are detailed.

5.2.1. S2.1 Preliminary Evaluation

First substage of the execution stage. It consists of the implementation of the property checklist inspection method, to evaluate the usability of the system, product, or service in a preliminary way.

Property Checklists

The use of the property checklist evaluation method [39] as the first inspection method to be executed in the proposed methodology, aims to quickly detect the deficiencies or pain points that can be found in the evaluated system, product, or service. Conducting this initial assessment will allow the evaluators to quickly make decisions about how to proceed with further assessments, if necessary.

Given the diversity of systems, products or services and objectives that research may have, it is necessary to select the property checklist instrument that best suits this purpose and, if necessary, adapt or create a new property checklist. The selection, adaptation or creation of a property checklist will depend on the judgment of the researchers.

Given the lack of property checklists that consider the characteristics and needs of people with ASD, we have proposed our property checklist to evaluate systems, products

or services used by people with ASD [15]. This proposal takes as a theoretical basis our proposal of nine UX factors for people with ASD [10].

Table A8 presents a brief specification of the execution of the property checklist method (see Appendix A), considering the inputs (elements necessary to start the execution of the method), execution steps (details on the execution of the evaluation method) and outputs (set of information and documents obtained after the execution of the method) that are relevant when implementing this evaluation method.

5.2.2. S2.2 Inspections

Second substage of the execution stage. The inspection substage considers three inspection methods: group-based expert walkthrough, perspective-based inspection, and heuristic evaluation. Next, each evaluation method will be explained in detail.

Group-Based Expert Walkthrough

The use of group-based expert walkthrough [40] allows us to identify potential usability problems, possible design improvements and solutions to these problems, through a group inspection carried out in conjunction with professionals "with practical experience" in the domain. The evaluation is based on the execution of a set of tasks–scenarios guided by a leader. The evaluation can be carried out using specific criteria of the domain under study, which are familiar to professionals who do not necessarily have knowledge about the UX. Consider that an expert with knowledge in both areas (UX/Usability and in the ASD domain) or a UX/Usability expert should take the lead role in the evaluation.

By using a group-based expert walkthrough inspection, we can easily include experts in the domain to the evaluation, as they do not need to have previous experience in executing UX/Usability evaluations. This can result in a greater amount of identified potential problems that are relevant for people with ASD and their characteristics.

Table A9 presents a brief specification of the execution of the group-based expert walkthrough method, considering the inputs, execution steps, and outputs (see Appendix A) that are relevant when implementing this evaluation method.

Perspective-Based Inspection

An inspection method that focuses on the identification of specific usability problems through three main perspectives [41]. These perspectives are based on three types of users: novice, expert, and error-handling. Each evaluator assumes the role and point of view of a user and inspects the system, product or service under that user role, guided by a set of inspection questions for each perspective. Zhang et al. [41] recommends creating the inspection questions based on an HCI model, for which we recommend considering our nine UX factors [10], and the perspectives, which can include a novice and expert user with ASD.

When executing the method, ASD domain experts should support UX/Usability experts if possible. Domain experts may find it easier to put themselves in the shoes of a user with ASD and therefore find specific problems that UX experts may not recognize.

Table A10 presents a brief specification of the execution of the perspective-based inspection method, considering the inputs, execution steps, and outputs (see Appendix A) that are relevant when implementing this evaluation method.

Heuristic Evaluation

An inspection method that focuses on finding potential usability problems in systems, products, or services. This method [9] is based on the inspection of evaluators, who look for potential problems based on different sets of previously selected heuristics, while specifying their severity, frequency, and criticality. When using the heuristic evaluation method, the use of tasks and scenarios is optional, and its realization will depend on the investigators.

Consider evaluating the system, product, or service through one or more sets of heuristics that consider the characteristics and needs of people with ASD. These are our suggested heuristic sets:

- Khowaja and Salim [42] present a set of 15 system-specific heuristics for children with ASD. These 15 heuristics were created through the adaptation and extension of the Nielsen heuristics [43], based on a study of the characteristics of people with ASD.
- We are currently developing a set of heuristics to evaluate systems, products, or services for adults with ASD. For the creation of this set of heuristics, we followed the methodology proposed by Quiñones et al. [44], considering as a basis our proposal of nine UX factors for people with ASD [10].

Table A11 presents a brief specification of the execution of the heuristic evaluation method, considering the inputs, execution steps and outputs (see Appendix A) that are relevant when implementing this evaluation method.

5.2.3. S2.3 User Tests

Once the inspections substage is finished or in parallel, the execution of at least one user test is required. Implementing tests with users' aims to find problems and measure the satisfaction of the participants after their interaction with the system, product, or service.

The user testing substage contemplates two methods: field observation and controlled observations. For both evaluation methods we recommend:

- Informing and instructing the user about the experiment, prior to carrying it out. Information and instructions must be clear and concise, prioritizing textual and/or visual communication.
- The interaction with the user, throughout the experiment, must consider the specific characteristics that the participant may present (e.g., not having any contact or physical proximity with people with ASD who may react negatively to this action).
- Having the consent of users or tutors (if necessary). Inform users and tutors that all information obtained will be treated anonymously.
- Keeping in mind throughout the experiment the dependence and autonomy of each of the participants. Sometimes the participants may require support from a tutor or a professional to help them.
- Obtaining the support of one or more tutors in case of any unforeseen event (if necessary). The tutor(s) can guide the user in the tasks to be carried out when necessary and/or assist the evaluators in identifying potential problems that may occur during the execution of the test.
- The investigator(s) should take on an observer role. Observers must not interfere during the experiment unless it is strictly necessary.
- Recording if the tutors or researchers have had to help the participants or interrupt the experiment, because the results obtained may be different or vary.
- Recording interactions with the system, product, or service through audiovisual recordings, always maintaining the anonymity of the user.
- Observers must record what they observed during the sessions in writing. We recommend recording the following information [45,46]: (1) activity performed, (2) actions, events and behaviors observed by users, (3) possible cause of the problem, considering the characteristics of the user, (4) description of the user (to identify the user more quickly in the audiovisual record).

More details of each evaluation method are given below.

Field Observation

Field observation aims to obtain information from users and detect potential problems of the system, product, or service to be evaluated [39]. These potential problems are detected while observing the user interacting with the system, product, or service in a natural environment. When using the field observation method, we recommend:

- Scheduling one or more observation sessions for users. Each session must have an estimated duration.
- During sessions, users should always be in an environment that is familiar to them. It is for the same reason that it is recommended not to interrupt users' activities and not to distract users by including elements outside their usual environment.

Table A12 presents a brief specification of the execution of the field observation method, considering the inputs, execution steps, and outputs (see Appendix A) that are relevant when implementing this evaluation method.

Controlled Observation

Controlled observation aims to identify potential problems that users may experience when interacting with the system, product, or service [39]. Controlled observation consists of the execution of guided activities, to eliminate the noise of the data obtained by including strict controls, such as the ordering of tasks, thus minimizing the possible effects of knowledge transfer between tasks and avoiding repetitive actions. When using the controlled observation method, we recommend:

- Recording the times that the participants have required to develop each task.
- Have a controlled environment, free from noise and visual distractions. If possible, make observations of the user in an appropriate laboratory.

Table A13 presents a brief specification of the execution of the controlled observation method, considering the inputs, execution steps, and outputs (see Appendix A) that are relevant when implementing this evaluation method.

5.3. S3 Results Analysis Stage

In this stage the organization and analysis of the results obtained after the execution of the evaluation methods in the execution stage is performed. The purpose of this stage is to organize the information, generate quantitative and qualitative analysis, and create a UX report that includes the main problems found, an analysis of these problems, as well as proposals for solutions to improve the UX of the product, system, or service.

As complementary material, Table A14 is presented in Appendix A. This table describes what is needed, what to do and what is obtained as an output when implementing this stage.

5.3.1. S3.1 Grouping of Potential Problems

The first substage is the grouping of the problems obtained in the execution of the evaluation methods. These problems come from different methods and documents, and the result is a consolidated list of potential problems.

The other documents obtained as outputs in previous stages, such as task lists, preliminary and perception questionnaires, will be used in the analyses without prior grouping.

Consolidating the identified potential problems requires grouping the problems and then identifying the ones that come up repeatedly. To perform this task:

- Group the potential problems found in the inspection methods: heuristic evaluation, group-based expert walkthrough and perspective-based inspection. Create a consolidated list with the unique potential problems found in the lists obtained in these methods, including the values of severity, frequency, and criticality of each evaluator for each problem. Furthermore, consider modifying the problem titles and definitions if this helps improve the clarity, quality, and consistency of the final consolidated listing.
- In case of having repeated potential problems, each one should be merged into a single potential problem by averaging the values of severity, frequency, and criticality of the repeated problems, and then defining a consolidated title and definition for it.

5.3.2. S3.2 Quantitative Analysis

The quantitative information can come from different sources: through the results obtained in the execution of the property checklist method, consolidated list of potential problems, task lists, answers obtained in the perception questionnaires and answers to the preliminary questionnaires (demographic). To perform the quantitative analysis, analyze the data obtained in the following categories:

- *Results of the property checklist*: After verifying compliance with the items of the checklist used, the satisfaction percentage of the system, product or service can be obtained, as shown in Table A8 (see Appendix A). As stated in our proposed property checklist [15] we recommend that evaluators rate each of the items on a scale of 1 to 5, from "Totally non-compliant" to "Totally compliant". Establishing a scale from 1 to 5 will allow the researchers to determine the compliance of each item of the property checklist. In addition, if categories are established, as in our proposal [15], we recommend evaluating compliance with each of the proposed categories as a group. To analyze these results, we recommend calculating and graphing the percentages of compliance by category, as well as calculating the global percentage obtained after the evaluation, which will allow us to clearly know the results obtained after completing the property checklist. A graphic way of visualizing the results obtained can be using radar charts [47].
- *List of potential problems*: For the potential problems obtained from the inspection methods grouped in substage S3.1, calculate the average and standard deviation of each of the severities, frequencies and criticalities assigned by each evaluator for each potential problem. A lower value of standard deviation may mean less discrepancies between evaluators; on the other hand, a higher value of standard deviation implies a notorious discrepancy between evaluators, so it is important to analyze these potential problems in detail. In addition, we recommend ordering the potential problems based on the average severity and criticality, to identify the potential problems that must be addressed with the highest priority.
- *List of tasks*: In the evaluation methods where the system, product or service is examined following a set of tasks, document the results and times required for the fulfillment of said tasks. From this, comparisons can be generated between the obtained results and times versus the expected results and times.
- *Preliminary questionnaire (demographic)*: It is important to capture information from the participants and evaluators, such as their age, gender, experience in the use of similar systems, products, or services, among others. We recommend that for each of the evaluation methods the captured information be graphed, to identify patterns and facilitate its analysis.
- *System, product, or service perception questionnaire*: Organize and graph the information captured through Likert scales to obtain a graphic display of the perception of the participants and evaluators and thus facilitate its analysis and identify patterns.

5.3.3. S3.3 Qualitative Analysis

The qualitative information can come from different sources: the perception questionnaires obtained in the executed methods, the task lists, the observers' logs, and audiovisual and written records. To perform the qualitative analysis, consider for each result previously obtained:

- *Task list:* For evaluation methods where the system, product or service is examined following a set of tasks, we recommend documenting the comments and the correct and incorrect actions carried out by the participants and/or evaluators.
- *Audiovisual and written records:* Organize and complement the written records obtained by the observers through the audiovisual records. These records can be based on the comments of the evaluators, as well as other aspects found when reviewing the captured audiovisual record.

- *Observer Logs:* Organize the information documented by the observers, such as comments and/or correct and incorrect actions carried out by the participants throughout the execution process of the evaluation method.
- *List of Comments and Recommendations:* Create a consolidated list that includes all the comments and recommendations identified through the perception questionnaires in each of the evaluation methods carried out, as well as those consolidated in the list of tasks, audiovisual records, and logs mentioned in the previous points. For this, it is recommended to group the comments and/or recommendations of all the outputs into common and easy-to-understand categories, such as the proposed UX factors for people with ASD [10]. Repeated comments must be merged into a single new comment. Organizing and consolidating these comments and recommendations will make it possible to find common patterns, positive and negative aspects, as well as identify general and specific problems that have not been formally found through the methods.

5.3.4. S3.4 UX Report

After carrying out the detailed quantitative and qualitative analyses in the previous substages, the final stage of the methodology corresponds to the integration and interpretation of the results, which can be used to generate a detailed report on the UX in the system, product or service evaluated, highlighting the potential problems found and providing recommendations to improve the UX.

Considering the previous analyses, a single consolidated report on the UX of the system, product or service must be generated, which is considered the final output of the methodology to evaluate the UX in systems, products or services for people with ASD. To prepare this report, consider:

- We recommend that the UX evaluation report be organized first according to the evaluation methods executed, and then have a section for general results.
- *Results of methods:* Provide a consolidated analysis and interpretation of the information obtained in each of the experiments carried out with the selected methods, including potential problems found, conclusions and recommendations. Include interpretations of each of the graphs created with the information from the evaluations carried out.
- *Quantitative Analysis:* Include a section of general quantitative results where the potential problems found between the different evaluation methods are related, including, for example, most common potential problems, ranking of problems according to their general criticality, observations found when comparing the results of the methods and any other information that is relevant to improve the UX of the system, product, or service. The quantitative information can be classified and organized based on the established UX factors [10], or other criteria that the researchers deem convenient.
- *Qualitative Analysis:* Include a comments and qualitative analysis section, which presents an overview of the evaluation and includes the qualitative results analyzed in substage S3.3. For this analysis, it is important to highlight common patterns found in the comments of all the experiments, positive aspects, negative aspects, and any other information that is considered relevant to improve the UX of the system, product, or service. This analysis can be supported by the quantitative results of the report.
- *Recommendations and Proposed Solutions:* Include a section in the report where researchers present recommendations to solve the problems previously described in the report with a UX perspective, as well as recommendations that are considered relevant for future evaluations.

Once the UX report is completed, it can be used by the developers and/or stakeholders of the system, product, or service, to improve the UX of people with ASD by fixing the problems found and applying the recommendations provided.

6. Validation and Discussion

Considering our preliminary proposal of the methodology [11], we have improved the methodology based on the opinions of three UX expert researchers. In this, each stage and substage have been detailed and restructured, and we included a new substage: S1.2 (Experiment Design). After consolidating these changes in a new version of the methodology, an expert judgment validation has been carried out, with 22 experts that have knowledge about UX/Usability, ASD, or both.

The experts' profiles include academic researchers, PhD students, computer scientists with UX/Usability expertise, and domain specific experts, such as speech therapists, psychologists, counselors, and educators with hands on experience working with people with ASD. Some of these experts have experience in both UX/Usability and ASD, and some have ASD themselves.

In the expert judgment validation, each participant has been given a specification document of the methodology, which includes a summarized version and a detailed version, and a survey which was created based on the proposal from Quiñones et al. [44]. The validation carried out is aimed at obtaining feedback from experts.

The survey has been divided into three sections.

(1) *First section:* Learn about the background of the participating experts.

(2) *Second section:* Evaluate the stages and substages of the methodology, using a five-level Likert scale (1—worst to 5—best) in four factors (F1, F2, F3 and F4):

- (F1) Usefulness: How useful do you consider each stage and substage of the methodology?
- (F2) Clarity: How do you rate the clarity of each stage and substage of the methodology?
- (F3) Ease of use: How easy would it be to implement each stage and substage of the methodology?
- (F4) Lack of Detail: Do you think that the stages and/or substages of the methodology need more detail or additional elements?

(3) *Third section:* Know their opinions about the methodology, the stages and substages, which includes:

- Two questions (Q1 and Q2) focused on finding out their general opinion about the methodology, through a five-level Likert scale (1—worst to 5—best).
    - (Q1) Use in future evaluations: If you had to evaluate the user experience in systems, products or services used by people with ASD, would you use our proposed methodology?
    - (Q2) Completeness: Do you think that the methodology covers all the aspects to be evaluated in systems, products or services used by people with ASD?
- Five open questions focused on knowing their opinions and comments on the methodology, stages and substages.
    - (O1): Would you remove or add any evaluation method proposed by the methodology? Which one(s) and why?
    - (O2): Would you change, add, or eliminate any aspect of a stage or substage of the methodology? Which one(s) and why?
    - (O3): Would you change, add, or eliminate any aspect of the evaluation methods considered in the proposed methodology? Which one(s) and why?
    - (O4): What aspects do you consider were not covered by the proposed methodology and should be included in the methodology to evaluate systems used by people with ASD?
    - (O5): Do you have any additional comments and/or suggestions for the authors?

The following results were obtained from this survey.

6.1. Experts Background

To know about the backgrounds of the 22 experts, they have been asked about their previous knowledge about UX/Usability and ASD. As a result, we have obtained the following information:

- A total of 20 experts (90.90%) previously knew the concepts of UX/Usability.
- A total of 21 experts (94.45%) previously knew the ASD concept. From this 94.45%:
  - A total of eight experts (38.09%) mentioned that they have interacted with people with ASD, because they have relatives and/or are people diagnosed with ASD.
  - A total of 13 experts (61.90%) mentioned that they have taught, researched, or carried out experiments with people with ASD.

6.2. Quantitative Results

Table 1 shows the results obtained by each of the factors (F1–F4). The information obtained is analyzed below.

Table 1. Results for factors F1, F2, F3 and F4.

	F1—Utility		F2—Clarity		F3—Ease of Use		F4—Lack of Detail	
	AVG	**SD**	**AVG**	**SD**	**AVG**	**SD**	**AVG**	**SD**
S1: Planning Stage	4.82	0.50	4.36	0.73	3.73	0.77	2.59	1.26
S1.1: Method Execution Planning	4.77	0.53	4.23	0.81	3.73	0.83	2.64	1.43
S1.2: Experiment Design	4.82	0.50	4.41	0.73	3.55	0.96	2.32	1.36
S1.3: Evaluators Selection	4.73	0.63	4.45	0.67	3.59	0.91	2.45	1.30
S1.4: Participants Selection	4.77	0.53	4.27	0.70	3.36	1.09	2.73	1.39
S2: Execution Stage	4.82	0.50	4.41	0.85	3.68	0.99	2.50	1.41
S2.1: Preliminary Evaluation	4.64	0.58	4.45	0.80	3.91	0.92	2.41	1.37
S2.2: Inspections	4.59	0.67	4.59	0.59	3.64	0.95	2.50	1.47
S2.3: User Tests	4.86	0.47	4.50	0.67	3.18	1.14	2.55	1.37
S3: Results Analysis Stage	4.91	0.29	4.41	0.85	4.00	0.93	2.18	1.33
S3.1: Quantitative Analysis	4.68	0.57	4.36	0.90	3.91	1.02	2.23	1.38
S3.2: Qualitative Analysis	4.77	0.43	4.36	0.85	4.00	0.93	2.18	1.30
S3.3: Integration of Results	4.82	0.50	4.23	0.97	3.68	0.89	2.32	1.43
	4.77		**4.39**		**3.69**		**2.43**	

It is important to mention that the methodology specification delivered to the experts only had three substages in the Results Analysis Stage. Considering the feedback from the experts, a new substage called "Grouping of potential problems" has been added, and substage S3.3 was renamed.

- (F1) Utility: The average utility of the methodology specification is high (4.77). Stage S3 (Results Analysis) is considered the most useful (4.91). The S2.2 substage (Inspections) is considered the least useful, however, its average is still high (4.59). The standard deviation is relatively low, ranging from 0.29 (stage S3) to 0.67 (stage S2.2). The standard deviation of stage S3 (Results Analysis) is the lowest of the four factors. The perceived usefulness of the methodology is high.
- (F2) Clarity: The average clarity of the methodology specification is high (4.39). Substage S2.2 (Inspections) is considered to have more clarity (4.59). Substages S1.1 (Method Execution Planning) and S3.3 (Integration of Results) are considered less clear (4.23). The standard deviation varies between 0.59 (substage S2.2) and 0.97 (substage S.3.3). The perceived clarity about the methodology is high. Considering the results obtained, the specification of the less clear perceived substages (S1.1 and S3.3) have been improved.
- (F3) Ease of use: The average ease of use of the methodology specification is moderate (3.69). Stage S3 (Results Analysis) and substage S3.2 (Qualitative Analysis) are considered to be the easier to use (4.00). Substage S2.3 (User Tests) is considered the most difficult to perform (3.18) and is the one with the highest standard deviation

(1.14); experts commented that this stage has been considered the most difficult to carry out, due to the unforeseen events that may arise and the various profiles that people with ASD may have, and not necessarily due to the complexity of the substage specification. Standard deviations are relatively high, ranging from 0.77 (stage S1) to 1.14 (substage S2.3).

- (F4) Lack of Detail: The average lack of detail in the specification of the methodology is low (2.43). Due to the nature of the question, having a low average does not imply having obtained negative results. A high average means that the methodology is missing more details. The substage S1.4 (Selection of Participants) is the one with the highest average (2.73). Stage S3 (Results Analysis) and substage S3.2 (Qualitative Analysis) are the ones with the lowest average (2.18). Standard deviations are high, ranging from 1.26 (stage S1—Planning) to 1.47 (substage S2.2—Inspections). Expert opinions on the F4 factor are divergent/mixed.

The experts' perceptions of the factors are homogeneous, except for factor F4. Because substage S2.3 (User Tests) is perceived as having a high utility (4.86), with a low ease of use (3.18) and a comparatively high need for more detail (2.55), it is that its specification and ease of use have been improved. Additionally, greater detail has been provided in the specification of substages S1.1 (Method Execution Planning) and S3.3 (Integration of Results) since they have been considered the least clear (4.23).

The results obtained in the two general questions (Q1 and Q2) on the methodology can be seen in Table 2.

Table 2. Planning Stage Specification.

	Q1—Intention of Use in Future Evaluation	Q2—Completeness
Average	4.32	3.77
Standard Deviation	0.72	0.75

These results show that:

- The perception of the experts regarding the use of the methodology in future evaluations (Q1) is high (4.32). A total of 86% of the evaluators perceive that they would probably and/or definitely use the proposed methodology to evaluate systems, products or services used by people with ASD.
- The experts' perceptions regarding the completeness of the methodology (Q2) are relatively high (3.77). Experts emphasize that working with people with ASD is not an easy thing to do. A total of 77% of the evaluators declare that the methodology probably and/or definitely covers all the necessary aspects to evaluate systems, products or services used by people with ASD.

6.3. Qualitative Results

When experts have been asked if they would remove or add any evaluation methods to the proposed methodology (O1), most have mentioned that they would not remove or add any evaluation methods. They mention that the chosen methods are relevant to the context to be applied.

When experts have been asked if they would change, add, or remove any aspect of a stage or substage (O2), experts have provided various comments. Table 3 shows the comments of the experts, if the suggestion has been considered, and the justification or action performed.

Table 3. Results of questions O1 and O2.

Comment	Has Been Considered?	Justification/Action
Previously train the participant with ASD, because eventually this new situation can cause stress.	No	The results of the tests with users can be biased if an induction is carried out beforehand. Emphasis has been placed on providing clear and concise instructions before and during the experiment.
Add more detail in the user testing substage.	Yes	Greater detail has been provided in substage S2.3, emphasizing the considerations that must be kept in mind when interacting with people with ASD.
Specify the number of participants, and if there will be a control group (with people without ASD) and/or an experimental group.	Yes	It has been detailed that the experiments should be carried out with people with ASD. It is recommended to have three or five participants with ASD [38].
Detail the faculties that the tutor will have during the tests with users.	Yes	It is detailed that the tutors must provide support to the participants, in case they are overwhelmed or do not understand the tasks to be carried out.

When the experts have been asked if they would change, add, or delete any aspect of the proposed evaluation methods (O3), the experts have mentioned various comments. Table 4 shows the comments of the experts, if the suggestion has been considered, and the justification or action performed.

Table 4. Results of question O3.

Comment	Has Been Considered?	Justification/Action
Consider possible problems in the estimated times for each planned task.	Yes	The suggestion was added as something to consider when planning the user tests.
Document if the participants have answered the preliminary and/or perception questionnaires with the support of the tutors or autonomously.	Yes	This has been included in substage S2.3.

When the experts have been asked about what aspects they consider were not covered by the methodology and should be included (O4), the experts have mentioned various comments. Table 5 shows the comments of the experts, if the suggestion has been considered, and the justification or action performed.

Table 5. Results of question O4.

Comment	Has Been Considered?	Justification/Action
Add a new stage, substage or product that details a possible "contingency plan".	No	We believe that the detail provided is sufficient as a basis for how to act in adverse situations.
Specify the link of the methodology and evaluation methods with the characteristics of people with ASD and/or proposed UX factors.	Yes	The suggestion has been included. The evaluation methods and the proposed UX factors [10] were selected/created based on the characteristics of people with ASD. It is recommended to particularize the instruments used in the evaluation methods for people with ASD.

When the experts have been asked if they have any additional comments and/or suggestions (O5), the experts have mentioned various comments. Table 6 shows the comments of the experts, if the suggestion has been considered, and the justification or action performed.

Table 6. Results of question O5.

Comment	Has Been Considered?	Justification/Action
The number of evaluators should be as proposed by Nielsen and Landauer [38].	Yes	The suggestion has been included in substage S1.3, evaluators selection.
The methodology should consider the dependency and/or autonomy of people with ASD.	Yes	This suggestion has been included in S1 planning stage.

Expert feedback is positive. It is pointed out that the methodology is complete, replicable, and modern. It is highlighted that the methodology can help a better inclusion of people with ASD, and that it can be difficult to carry out tests with users with people with ASD. We have realized the need to modify the structure of stage S3 (Results Analysis Stage) and created sub-stages S3.1 (Grouping of potential problems) and S3.4 (UX Report), to provide better clarity for this stage. It should be noted that stage S3 (Results Analysis Stage) has only had a change in the structure and not in its content.

Considering the comments and suggestions provided by the evaluators, it has been possible to refine the proposed methodology, as presented in this document.

7. Conclusions

Studies have evaluated the UX and/or usability of their technological proposals through various evaluation methods and instruments, with the support of experts in ASD, people with ASD and their parents and/or tutors. Many of the evaluation methods and/or instruments used are not particularized or do not consider the characteristics of people with ASD. The investigations do not provide enough detail of the evaluations carried out [6].

It is necessary to have evaluation methods and instruments that consider the characteristics of people with ASD, with a special emphasis when these methods and instruments are executed with people with ASD; therefore, a formal process when evaluating the UX of systems, products or services used by people with ASD is needed.

We have followed a seven-stage process for the creation of the methodology to evaluate the UX of systems, products or services used by people with ASD. This process is backed up by (1) the publication of a systematic literature review [6], which represents a justification for the need of a formal evaluation process, (2) the creation of nine UX factors for people with ASD [10], that has supported the characterization the users, and particularization of evaluation methods, instruments and processes aimed at evaluating UX in systems, products or services used by people with ASD, and (3) the publication of a first iteration of the creation process that resulted in a preliminary proposal of the methodology [11].

Two validations were made to the preliminary proposal of the methodology [11]. Experts with knowledge in UX/Usability, in the ASD condition, and in both, have provided us with comments and suggestions. Many of the comments and suggestions made were considered. In the first validation, a greater specification of the methodology has been refined and provided, as well as the creation of the substage S1.2 (Experiment Design). In the second validation, modifications were made mainly in substage S2.3 (User Tests) and a restructuring of stage S3 (Results Analysis Stage).

Considering the results of the two validations carried out (two iterations in the creation process), we can highlight that the proposed methodology is perceived by the experts as useful, a contribution to the inclusion of people with ASD and, furthermore, they mention having the intention of using it in the future.

The proposed methodology establishes a formal process to evaluate the user experience in systems, products and services used by adults with ASD, which includes evaluation methods, instruments and processes that were selected and adapted according to the specific characteristics of the users. Using the proposed methodology with an adequate selection or adaptation of instruments, such as those recommended in this paper, can help to improve the satisfaction and perception of people with ASD about the system, product or service evaluated.

We believe that this methodology proposal contributes to solving the need for a formal process to evaluate the UX of systems, products or services used by people with ASD identified in the early stages of this investigation. By using this methodology, investigators will be able to follow a validated process that uses specific methods and instruments that were selected and adapted according to the needs of people with ASD, and by identifying and addressing the potential UX problems found, and the UX of the system, product or service can be improved, thus helping in providing a positive and rewarding experience for users with ASD.

In future work, we intend to apply the proposed methodology to evaluate the user experience in a system designed for people with ASD and a website not designed for people with ASD. We aspire to apply the methodology with the support of experts with knowledge in UX/Usability, ASD, and both, as well as to have the support of young adults diagnosed with ASD.

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Appendix A

Table A1. Planning Stage Specification.

S1: Planning Stage Plan UX evaluations to be performed. Find experts, participants, and tutors.	
What do I need to get started?	• Select a specific system to evaluate UX
What to do?	• Collect information about the system. • Selection of evaluation methods to be performed. • Identify and describe goals, protocols, scenarios, tasks and expected results of the evaluation. • Selection of participants with ASD *, tutors **, UX/Usability experts and ASD domain experts. * Participants must be within the objective users of the system, product, or service to be evaluated. ** Considering the dependence and autonomy of the participants, we recommend having the support of tutors or evaluators who can help the participants with problems or questions.
What is obtained?	• ① System, product, or service information. • ② List of methods to execute. • ③ Experiment Design Document. • ④ List of evaluators. • ⑤ List of participants.

Table A2. Method Execution Planning Specification.

S1.1 Method Execution Planning Selection and planning of methods to be executed.	
What do I need to get started?	• ① System, product, or service information.
What to do?	• Collect system, product, or service information. • Define objective and scope of the UX evaluation. • Select the evaluation methods to be carried out based on the objective, scope, resources, and available time. It is recommended that: ○ If there are no time and resource constraints, it is suggested to perform all the methods proposed in the methodology (Figure 1). ○ If there are time and resource constraints, it is recommended to follow the simplified sequence: property checklist, heuristic evaluation and field observation. ○ Otherwise, select the methods to be performed according to the time and resources available, considering the complexity of each method (see S1.1 Method Execution Planning).
What is obtained?	• ② List of methods to execute.

Table A3. Rating Scales of Problems Detected.

Rating Scale	Description	Range	Scale
Severity	Scale that evaluates how detrimental the potential problem is to the use of the system.	0–4	(4) Catastrophic problem; (3) major problem; (2) minor problem; (1) cosmetic problem; (0) it is not a problem
Frequency	Scale that evaluates the occurrence of the problem during use of the system.	0–4	(4) >90%; (3) 51–90%; (2) 11–50%; (1) 1–10%; (0) <1%
Criticality	Sum of the assigned severity and frequency, which represents the level of criticality of the problem.	0–8	

Table A4. Experiment Design Specification.

S1.2 Experiment Design Design and specify the experiments to be performed.	
What do I need to get started?	• ① System, product, or service information. • ② List of methods to execute.
What to do?	• Collect system, product, or service information. • Define the evaluation objective(s) for each method to be carried out. • Define expected results to be obtained in each evaluation. • Scenario creation *. • Task set creation *. • Protocol creation. The protocols contemplate a set of documents required for the execution of the evaluation methods. • Consolidate the information in the "Experiment Design document". * It is recommended, if possible, that aspects, such as scenarios and tasks, are universally defined to use in multiple evaluation methods.
What is obtained?	• ③ Experiment Design Document.

Table A5. Evaluators Selection Specification.

S1.3 Evaluators Selection Search and selection of evaluators.	
What do I need to get started?	• ① System, product, or service information.
What to do?	• Analyze system, product, or service information. • Select experts in UX/Usability, experts in the ASD domain and/or experts with knowledge in both areas (UX/Usability and in the ASD domain). • Select a leader with knowledge in both areas (UX/Usability and in the ASD domain) or a UX/Usability expert. • Collect information from expert evaluators. • Consolidate the list of expert evaluators.
What is obtained?	• ④ List of evaluators.

Table A6. Participants Selection Specification.

S1.4 Participants Selection Search and selection of participants with ASD and their tutors.	
What do I need to get started?	• ① System, product, or service information.
What to do?	• Define target users. • Search for participants with ASD. ○ Have the permission of the guardians if necessary. • Search and list tutors, if needed. ○ It is recommended that they are people close to the participants with ASD. • Collect the information obtained from the participants. • Consolidate the list of participants.
What is obtained?	• ⑤ List of participants.

Table A7. Execution Stage Specification.

S2: Execution Stage Execution of selected evaluation methods.	
What do I need to get started?	• ② List of methods to execute. • ③ Experiment Design Document. • ④ List of evaluators. • ⑤ List of participants.
What to do?	• Collect information obtained in the planning stage. • Evaluators training. • Execute the preliminary evaluation. • Execute the inspection methods. • Execute user tests. • Document the results obtained in each of the evaluations.
What is obtained?	• ⑥ Results of the execution of the preliminary evaluation. • ⑦ Results of the execution of the inspection method(s). • ⑧ Results of the execution of the user test(s).

Table A8. Property Checklist Specification.

Property Checklist	
Input	• ③ Experiment Design Document: ○ Goals. ○ Protocol. ○ Scenarios (Optional). ○ Tasks (Optional). ○ Expected results. • Checklist tool/s to use. • ④ List of evaluators.
Execution Step	• For further details and specification of the method refer to study [39]. • We recommend that the evaluators must indicate compliance with each of the items on the checklist provided and may also add comments for each item or in general.
Output	• Percentage of system, product, or service satisfaction for people with ASD *. ○ Percentage of satisfaction per category ** = (average score per category/maximum score to be achieved) × 100. ○ Total satisfaction percentage = average percentage of satisfaction of all categories. • System Perception Questionnaire. ○ Comments and/or recommendations of the evaluators. • Preliminary questionnaire (Demographic). * The percentage of satisfaction of the system considers that each item of the property checklist will be evaluated on a Likert scale, as proposed in our property checklist adaptation [15]. ** It is proposed to categorize the items of the property checklist [15], to obtain an overview of the successes and failures in the design of the evaluated system, product or services.

Table A9. Group-Based Expert Walkthrough Specification.

Group-Based Expert Walkthrough	
Input	• ③ Experiment Design Document: ○ Goals. ○ Protocol. ○ Scenarios. ○ Tasks. ○ Expected results. • ④ List of evaluators.
Execution Step	• For further details and specification of the method refer to the study [40]. • The author of the group-based expert walkthrough method only proposes the assignment of the severity scale [40]. For the purposes of the methodology, we recommend using the frequency and criticality scales.
Output	• List of potential problems. ○ Details about severity, frequency and criticality can be found in Table A3. • List of tasks performed. ○ Document completed by the evaluators. • System Perception Questionnaire. ○ Comments and/or recommendations of the evaluators. • Preliminary questionnaire (Demographics).

Table A10. Perspective-Based Inspection Specification.

Perspective-Based Inspection	
Input	• ③ Experiment Design Document: ○ Goals. ○ Protocol. ○ Scenarios. ○ Tasks. ○ Expected results. • ④ List of evaluators.
Execution Step	• For further details and specification of the method refer to the study [41]. • The authors of the perspective-based inspection method only propose the assignment of the severity scale. For the purposes of the methodology, we recommend using the frequency and criticality scales.
Output	• List of potential problems. ○ There will be a list of problems for each perspective. ○ Details about severity, frequency and criticality can be found in Table A3. ○ The values of severity, frequency and critique are agreed by all the evaluators. • List of tasks performed. ○ Document completed by each evaluator. • System Perception Questionnaire. ○ Comments and/or recommendations of the evaluators. • Preliminary questionnaire (Demographics).

Table A11. Heuristic Evaluation Specification.

Heuristic Evaluation	
Input	• ③ Experiment Design Document: ○ Goals. ○ Protocol. ○ Scenarios (Optional). ○ Tasks (Optional). ○ Expected results. • ④ List of evaluators: • Set of selected heuristics.
Execution Step	• For further details and specification of the method, refer to study [9]. For the purposes of the methodology, we recommend using the frequency and criticality scales. • This stage can be a free exploration of the system, product or service or it can be guided by a set of tasks, depending on what is indicated in the execution plan.
Output	• List of potential problems. ○ Details about severity, frequency and criticality can be found in Table A3. • List of tasks performed *. ○ Document completed by each evaluator. • System Perception Questionnaire. ○ Comments and/or recommendations of the evaluators. • Preliminary questionnaire (Demographics). * Depending on the execution plan, it may or may not be necessary.

Table A12. Field Observations Specification.

Field Observations	
Input	• ③ Experiment Design Document: ○ Goals. ○ Protocol. ○ Expected results. • ⑤ List of participants.
Execution Step	• For further details and specification of the method refer to the study [39]. • Consider the general and specific recommendations of the evaluation method presented in Section 5.2.3 (S2.3 User Tests).
Output	• System Perception Questionnaire. ○ Comments and/or recommendations from the participants and/or tutors. Tutors are only part of the experiment if needed. • Audiovisual and written records. • List of potential problems. ○ Potential problems found by the evaluation observers. • Observers log. ○ List of observations about the behavior and involvement of users during interaction with the system. • Confidentiality agreement.

Table A13. Controlled Observations Specification.

Controlled Observations	
Input	• ③ Experiment Design Document: ○ Goals. ○ Protocol. ○ Scenarios. ○ Tasks. ○ Expected results. • ⑤ List of participants.
Execution Step	• For further details and specification of the method refer to the study [39]. • Consider the general and specific recommendations of the evaluation method presented in Section 5.2.3 S2.3 User Tests.
Output	• System Perception Questionnaire. ○ Comments and/or recommendations from the participants and/or tutors. Tutors are only part of the experiment if needed. • Audiovisual and written records. • List of potential problems. ○ Potential problems found by the evaluation observers. • Task list. ○ Completed by the participants. • Observers log. ○ List of observations about the behavior and involvement of users during interaction with the system. ○ Performance measures of the tasks performed (time and number of tasks performed). • Confidentiality agreement. • Preliminary questionnaire (Demographics).

Table A14. Results Analysis Stage Specification.

S3: Results Analysis Stage Analysis and report of the results found.	
What do I need to get started?	• ⑥ Results of the execution of the preliminary evaluation. • ⑦ Results of the execution of the inspection method(s). • ⑧ Results of the execution of the user test(s).
What to do?	• Group the results obtained from the evaluations carried out. • Quantitative analysis. • Qualitative analysis. • Create the UX evaluation report.
What is obtained?	• ⑨ Results of quantitative analysis. • ⑩ Results of qualitative analysis. • ⑪ UX evaluation report.

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