

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.



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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 hyper-reactive 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.

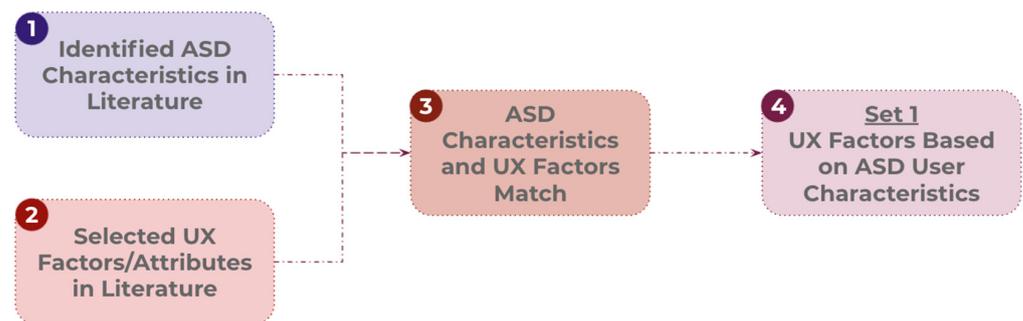


Figure 1. Process for Defining UX Factors Based on ASD User Characteristics.

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	<ul style="list-style-type: none"> • 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]. 	<ul style="list-style-type: none"> • 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 considered 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.

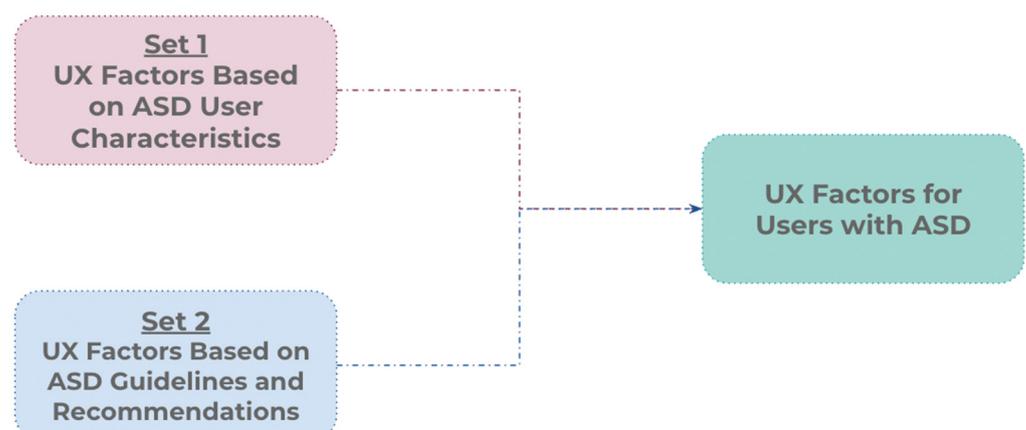
**Figure 3.** Process of Defining Final UX Factors for Users with ASD.

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	<ul style="list-style-type: none"> 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]. 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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]. 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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]. 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> • 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]. 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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]. 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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]. 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • People with ASD have difficulties when generalizing skills to real-world contexts [55]. 	<ul style="list-style-type: none"> • 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
Nature as a Healer for Autistic Children [48].	Participatory design
	Visual principle as a therapeutic tool
	Design elements as a therapeutic tool
	Physical landscape feature as a therapeutic tool
Designing and Evaluating Touchless Playful Interaction for ASD Children [34].	Landscape resources and materials as a therapeutic tool
	Design guidelines
	General guidelines
	Goal-specific guidelines: Motor skills
Design Considerations for the Autism Spectrum Disorder-Friendly Key Stage 1 Classroom [49].	Goal-specific guidelines: Cognitive skills
	Goal-specific guidelines: Social skills
	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	
Designing Visualizations to Facilitate Multisyllabic Speech with Children with Autism and Speech Delays [44].	Storage
	Computer provision
	Workstations
	Minimize delay to interaction
	Real-time is fun
Assessing the Target' Size and Drag Distance in Mobile Applications for Users with Autism [35].	Child customization
	Dynamic computer correction
	Robust microphone setup
	Competence of the child
	Physical interaction
	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
Towards a Serious Games Design Framework for People with Intellectual Disability or Autism Spectrum Disorder [37].	Simplicity
	Scoring
	Pedagogy
Development of the AASPIRE Web Accessibility Guidelines for Autistic Web Users [45].	Learning content and game mechanics
	Evaluation
	Physical accessibility
AutismGuide: Usability Guidelines to Design Software Solutions for Users with Autism Spectrum Disorder [46].	Intellectual accessibility
	Social accessibility
	General usability principles
	Nonfunctional requirements
	Functional requirements for caregivers/partners
	Adaptability
	Guidance
	Workload
	Compatibility
	Explicit control
Towards Developing Digital Interventions Supporting Empathic Ability for Children with Autism Spectrum Disorder [39].	Significance of codes
	Error management
	Consistency
	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]
Generalizable	Goal	“There should be one unique explicit goal to reach within a gaming session.” [38]	[34,37,38]
	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]
	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]
Structure, Repeatability, and Predictability	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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