Exploring the Landscape of UX Subjective Evaluation Tools and UX Dimensions: A Systematic Literature Review (2010-2021)

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The quality of the User Experience (UX) with systems, products, and services is now considered an indispensable part of success in the market. Users' expectations have increased in such a way that mere usability is no longer sufficient. While numerous UX subjective evaluation tools exist, there is little guidance on how to select or use these tools. Therefore, there is a need to provide a critical state of the art on the topic of subjective evaluation tools and the UX dimensions covered. In this study, we conducted a systematic literature review on UX subjective evaluation tools and the UX dimensions covering the period of 2010-2021 with an initial sample of 3831 publications, 325 of which were selected for the final analysis, to provide researchers and practitioners with the recent changes in the field of UX. Results showed that 104 different tools are available for UX evaluation, they can be classified as general or domain-specific, applicable for a wide variety of products, and in total covering more than 300 UX dimensions. Our categorization of UX dimensions under 13 main dimensions (e.g., usability, utility, hedonic, emotion, sensory, etc.) showed that the informational, social, cognitive, and physical dimensions appeared to be less frequently present in current tools. We argue that these four dimensions deserve more space in UX tools. Having a high number of UX evaluation tools can be confusing for evaluators, and they need some guidance for selecting and combining tools. Modularity is the emerging trend in the development of UX evaluation questionnaires (e.g., meCUE, UEQ+), bringing the benefits of being thorough, flexible, easy to use, low-cost, and rapid, while avoiding overlapping of dimensions and providing comparability through the use of a similar format and rating scale. Finally, the need for having a comprehensive evaluation tool requires updating the set of included dimensions to accommodate for new generations of products and technologies.

CCS CONCEPTS: • Human-centered computing • Human-Computer Interaction (HCI)

Additional Keywords and Phrases: User experience, UX evaluation tool, UX dimension, systematic literature review, SLR

Research highlights

- The extensive range of products and the diverse contexts in which they have been investigated demonstrate the pervasive influence of user experience.
- Over the past decade, there has been a rise in the use of diverse evaluation tools across research studies.
- The user experience questionnaire (UEQ) and its variants (UEQ-S, UEQ+), along with AttrakDiff, stand out as the most commonly employed UX subjective evaluation tools.
- Existing UX evaluation tools predominantly cover usability, hedonic, utility, and sensory dimensions.
- Despite the increasing prevalence of products with social features, current UX evaluation tools often overlook the social dimension.

1 INTRODUCTION

The development of technology has enabled organizations to introduce systems, products, or services[1] that provide new features, engage more senses, and create new experiences for users. As technology evolved from the first generation of computers in the 1940s to today's ubiquitous devices, users shifted from engineers and highly trained professionals to general people (MacDonald & Atwood, 2013). The field of user experience (UX) has also grown and evolved since its introduction more than two decades ago to address the changes in users and industries.

The number of research initiatives in the field of UX has increased during this period. UX definition, UX dimensions, evaluation tools and methods are among the subjects that have been investigated in different studies. ISO 9241-210 defines UX as the "*user's perceptions and responses that result from the use and/or anticipated use of a system, product or service*" (Standardization, 2019). Although criticized (Kurosu, 2013), this definition is widely adopted in industry (Mirnig et al., 2015) and it also aligns with most researchers' perspectives on the subjective nature of UX (Law et al., 2009). Researchers in UX come from a variety of disciplines, including computer science, ergonomics, psychology, anthropology, graphic arts, software design, market research, and branding (Redish & Barnum, 2011). Many researchers tried to establish a somewhat universal definition of UX (Kim et al., 2015) but no consensus has been reached. Studies conducted in 2009, 2010, and 2015, references (Law et al., 2009), (Jaaskelainen & Heikkinen, 2010), (Lallemand et al., 2015), investigated the understanding of UX definitions among researchers from different disciplines. More recently, in 2017, the socio-cultural impacts of UX professionals on UX definitions have been studied, revealing divergent perspectives regarding the UX definition among these professionals (Rajanen et al., 2017).

UX dimensions are the different factors that influence the user-product interaction (Robert & Larouche, 2012) and have impact on the users' perceptions of their experience with the product. Pragmatic and hedonic dimensions are the two main UX dimensions identified in prior work (Hassenzahl, 2003). Functional or utilitarian aspects of the UX are addressed by pragmatic dimension while hedonic dimension is concerned with the non-task-related of the interaction like pleasure and aesthetics (Hassenzahl, 2003). Emotional, sensory, informational, social, and physical aspects are other UX dimensions mentioned in recent studies (Provost & Robert, 2013; Robert & Larouche, 2012). The UX dimensions considered, and their evaluation tools tend to change based on the researchers' disciplines and the types of products they are interested in for the UX. New UX dimensions are established to revamp the concept of UX in accordance with the introduction of new products (Santoso & Schrepp, 2019) and technologies; thus, evaluation methods and tools should be flexible to accommodate these changes.

UX evaluation can be done either by experts or end users. Experts observe or anticipate users' interaction with products, use heuristics, expert review, and cognitive walkthrough (Mashapa & Van Greunen, 2010), while end users can fill out questionnaires, participate in interviews, or think aloud while interacting with a product as methods to report on their UX.

[1] For the sake of brevity, only the term product is used in the following text.

According to ISO 9241, "*UX is the user's perceptions and responses that result from the use and/or anticipated use of a system, product or service. Users' perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviors, and accomplishments that occur before, during and after use.*" (Standardization, 2019). It confirms that the three categories of evaluation methods (i.e., behavioral, subjective, and physiological) are all applicable in the UX evaluation.

- Behavioral methods provide objective data on the users' actions and reactions towards a product, including strategies, performance, and errors. They are employed to observe what users actually do rather than what they claim to do. These data can be quantitative (e.g., task completion time, success rate, error rate, eye movements) or qualitative (e.g., facial, verbal, postural expressions) and can be collected in real time and remotely. This category of method is considered medium cost. However, behavioral methods cannot explain the reasons behind a user's actions.
- Subjective methods provide subjective data on the users' perceptions and appreciation of the product, and their workload when using the product. Aspects like the user's emotions, expectations, perceptions, judgments, satisfaction and values can be documented through these methods. In other words, they are about the user's overall experience with a product, so they are usually collected at the end of the experience, remotely or not. Interviews, questionnaires, scales, think aloud, writing and drawing exercises, and card & board methods (e.g., MAX[2]) are among the data collection methods of this category. In the case of using questionnaires or scales, this category of methods can be considered low-cost while enabling a large number of people to be reached at once. However, language, memory restrictions and the biasing effect of social desirability may be counted as shortcomings of subjective measurements (Holman & Adebesin, 2019).
- Physiological methods provide objective data by collecting voluntary and involuntary bodily responses during interaction with a product in real-time that overcome language and memory limitations (Federici et al., 2019). They collect data using the measurement of electrical activity of the brain, heart rate, pupil dilation, sweating, respiration rate, blood pressure, and muscle tension. Nonetheless, they are considered to be of high cost because they require investing in tracking equipment and devices, and data analysis abilities to process the data and make sense of the findings (Ibrahim et al., 2015; Soleimani & Law, 2017). The devices and sensors used in these methods can be intrusive and uncomfortable for the users who wear them and make remote evaluation difficult. Lastly, momentary evaluations is typical of psychophysiological but these evaluations in most cases do not reliably reflect the real-life experience with a product (Maia & Furtado, 2016)

Overall, these three methods do not take precedence over one another, rather, it is suggested to triangulate objective and subjective data provided by different methods to gain a holistic view of UX (Soleimani & Law, 2017). There is a need to provide a critical state of the art on the topic of subjective evaluation tools in general and questionnaires in particular as questionnaire are used the most among all UX evaluation tools (Bargas-Avila & Hornbaek, 2011).

The need for a systematic literature review (SLR) on UX subjective evaluation tools is threefold: previous SLRs used a limited number of databases (Maia & Furtado, 2016; Pettersson et al., 2018; Robinson et al., 2017), the studied time frame ended more than 5 years ago (Robinson et al., 2017; Zarour & Alharbi, 2017), and many included studies focused on a subset of questionnaires (Díaz-Oreiro et al., 2019). In this study, we conducted a SLR on UX subjective evaluation tools and the UX dimensions considered. We reviewed literature from 2010 to 2021 using four databases. We expected

[2] Method for the Assessment of eXperience

that conducting a SLR with more databases compared to previous SLRs, including the engineering field, would yield more reliable and comprehensive results. We focused on the UX dimensions evaluated by these tools and the products they were applied to. This is of interest since recent products introduced new UX dimensions that were not considered in previous research (Santoso & Schrepp, 2019), and investigating which products have been studied in recent years can help researchers update their tools and methods.

2 RELATED WORK

UX literature reviews have taken various forms such as snowballing study, SLR, and systematic mapping study to explain and classify different aspects of this field, like UX dimensions, UX evaluation tools and methods, evaluated products, types of collected data and more. In the years 2000-2010, researchers focused on the UX definition (Jaaskelainen & Heikkinen, 2010; Law et al., 2009) and the available tools and methods for UX evaluation (Roto et al., 2009; Vermeeren et al., 2010), and positioned the UX as a new concept that goes beyond usability. Roto et al. investigated 30 UX evaluation methods with professionals in academic and industrial contexts (Roto et al., 2009). Their work was completed by Vermeeren et al. who collected 96 UX evaluation methods from literature reviews, workshops, special interest groups and online surveys (Vermeeren et al., 2010). Their results are published on (*Experience Research Society*, 2023), listing 86 UX evaluation methods and their characteristics such as source of information, location, product development phase, and type of collected data, to name a few. The systematic literature review of Bargas-Avila and Hornbaek (Bargas-Avila & Hornbaek, 2011) is the main source for the following reviews in the field of UX (Pettersson et al., 2018; Rivero & Conte, 2017a; Robinson et al., 2017). They analyzed the empirical UX studies regarding the products, UX dimensions, and methodologies during the time period from 2005 to 2009 (Bargas-Avila & Hornbaek, 2011). Their findings showed that the context of use shifted from work to leisure, with evaluations in open use situations with consumer products. The most frequently evaluated UX dimensions were emotions, enjoyment and aesthetics, and studies mostly used qualitative methods (Bargas-Avila & Hornbaek, 2011).

From 2010 onward we observed the emergence of UX literature reviews on specific products like ubiquitous computing systems (Vaananen-Vainio-Mattila et al., 2015), information driven website (Ten & Paz, 2017), language management systems (Nakamura et al., 2017), interactive digital narratives (Revi et al., 2020), natural user interface (Guerino & Valentim, 2020), and Virtual Reality (VR) systems (Kim et al., 2020). Literature reviews investigating the state of the art in UX were published as well. Rivero and Conte (Rivero & Conte, 2017b) performed a systematic mapping study to discover the UX technologies (tools, methods, techniques) of software applications during the 2010-2015 time frame, but their work was limited to only one database (Scopus). The systematic review of Maia and Furtado (Maia & Furtado, 2016) revealed that psychophysiological evaluation methods have not been used extensively in UX studies, the number of studies with long term UX evaluation was low, and subjective UX evaluation tools like questionnaires were used more than all the other tools. Their work, however, was based on 25 papers only. The SLR by Robinson et al. (Robinson & Lanius, 2018; Robinson et al., 2017) followed the work of Bargas-Avila and Hornbaek by extending the time period from 2000 to 2016. In addition, they also explored empirical studies on UX regarding the use of research questions or hypotheses. They covered 400 empirical studies extracted from one database (google scholar). The work of Zarour and Alharbi (Zarour & Alharbi, 2017) reviewed UX publications with a focus on software and technology during the 2005-2015 timeframe and provided a better picture of UX studies including brand, user and technology experiences. Covering the period of 2010 to 2016, Pettersson et al. (Pettersson et al., 2018) investigated the triangulation of methods in UX studies published in eight ACM conferences. The most recent literature reviews are the work of Darin et al. (Darin et al., 2019) and Diaz et al. (Díaz-Oreiro et al., 2019). Darin and colleagues (Darin et al., 2019) used a snowballing procedure on the Vermeeren et al. list of UX

evaluation methods and provided an updated list of UX instruments developed up to 2018. However, their review missed recent UX subjective evaluation tools such as meCUE[3], MUX[4] and UEQ[5]+. Diaz and colleagues (Díaz-Oreiro et al., 2019) only reviewed three UX questionnaires (i.e., AttrakDiff, UEQ[6] and meCUE). The objective of this SLR is to build upon prior research and present to readers the most current trends in the field of UX.

3 METHODOLOGY

The present SLR was conducted based on the procedure proposed by Kitchenham and Charters (Kitchenham & Charters, 2007), that includes three main phases; planning the review, which includes establishing the research questions and determining the search strategy; conducting the review, which includes performing the search and refining the primary results based on the selection criteria, and reporting the review.

3.1 Planning the review

In this SLR, we reviewed UX empirical studies with interactive products. By empirical, we mean studies in which a real interaction took place between a user and a product (so the study presents user data). The SLR does not include studies with imagined products, expert reviews (e.g., heuristics), nor observer data. We excluded papers that used only interviews or think-aloud as subjective evaluation tools. However, insights concerning the usage of these tools in conjunction with other subjective evaluation tools such as questionnaires and scales are presented in the results and discussion sections. Finally, we consider usability as a dimension of UX. Therefore, to avoid conflating papers solely centered on usability with those encompassing it as part of UX, we took great care in reviewing each paper to ensure studies were genuinely measuring usability within the context of UX.

Research questions: we formulated three research questions:

RQ1- Which products, in which stage of development, where, when and how, were evaluated in the UX empirical studies?
RQ2- Which UX subjective evaluation tools were used?
RQ3- Which UX dimensions were covered?

Database selection: We selected four databases for the SLR. ACM Digital Library is a rich source in the field of Human-Computer Interaction, covering established conferences and journals like CHI[7] and TOCHI[8]. IEEE Xplore Digital Library and Web of Science were also incorporated to cover a wider range of scientific literature. Robinson and Lanius (Robinson & Lanius, 2018) showed that in addition to HCI and computer and information science, engineering journals also published UX studies. Therefore, we added Engineering Village as a comprehensive and multi-disciplinary database to ensure better coverage.

Time frame: The meta-analysis conducted by Bargas-Avila and Hornbaek (Bargas-Avila & Hornbaek, 2011), which focused on UX empirical studies from 2005 to 2009, yielded important insights into the latest trends of the UX field, included UX dimensions, and evaluation tools. To bring the UX literature up-to-date, we chose the 2010-2021 time frame for this SLR.

Search terms: A set of specific keywords were selected based on the research questions. The terms "User experience" and its shorter form "UX" were the main ones. A first group of terms that refer to UX dimensions in the literature like

[3] Modular evaluation of key components of user experience
[4] Mobile User eXperience
[5] User Experience Questionnaire plus
6 User experience questionnaire
[7] Conference on Human Factors in Computing Systems
[8] Transactions on Computer-Human Interaction

component, attribute, aspect, indicator, factor, dimension and element were also included. Additionally, evaluation, measurement and tool were the other group of terms applied in this SLR. The search strings for each database were formulated with the help of a librarian specialist and are provided in Appendix 1.

Inclusion criteria:

- The paper evaluates the UX of a product, system, or service.
- The publication type is a journal or a conference paper (including various types such as short papers or case studies).
- The paper has been published between January 2010 and April 2021.

Exclusion criteria:

- The paper does not mention the UX dimensions.
- The paper is not related to the domain of user experience.
- The evaluation tool/method used is not subjective (e.g., physiological, behavioral).
- The evaluation is done by someone other than the user (e.g., expert, observer).
- The product evaluated is not interactive.
- There is no interaction between the user and the product.
- The paper is written in a language other than English.
- The full text is not available.

3.2 Conducting the review

The scientific papers were searched in the subject, title and abstract fields for Web of Science and Engineering Village databases, in the abstract field for ACM Digital Library, and in all fields for Web of Science repositories. Search strings varied amongst databases because of different search functionalities, however they all used the same terms. The search was performed in April 2021 and produced 3831 papers (see **Error! Reference source not found.**). The results were imported to Endnote X9 for further evaluation. First, 1357 duplicates and papers that appeared in more than one database were removed. Second, the remaining 2474 publications were filtered to remove 75 papers that were not in English or had a format other than that of a journal article or conference paper (e.g., poster or abstract). The third step required reading the abstracts of 2399 papers to evaluate them based on the inclusion criteria. A small number of papers (31) in other fields like aeronautics, network, physics, and material science were removed because the term “UX” was used with a different meaning. An additional 868 papers in which UX was not the main subject of the paper and was only mentioned in the abstract or keywords were also removed. The full texts of 50 papers were not available and thus they had to be removed. Overall, 949 papers were removed in this step.

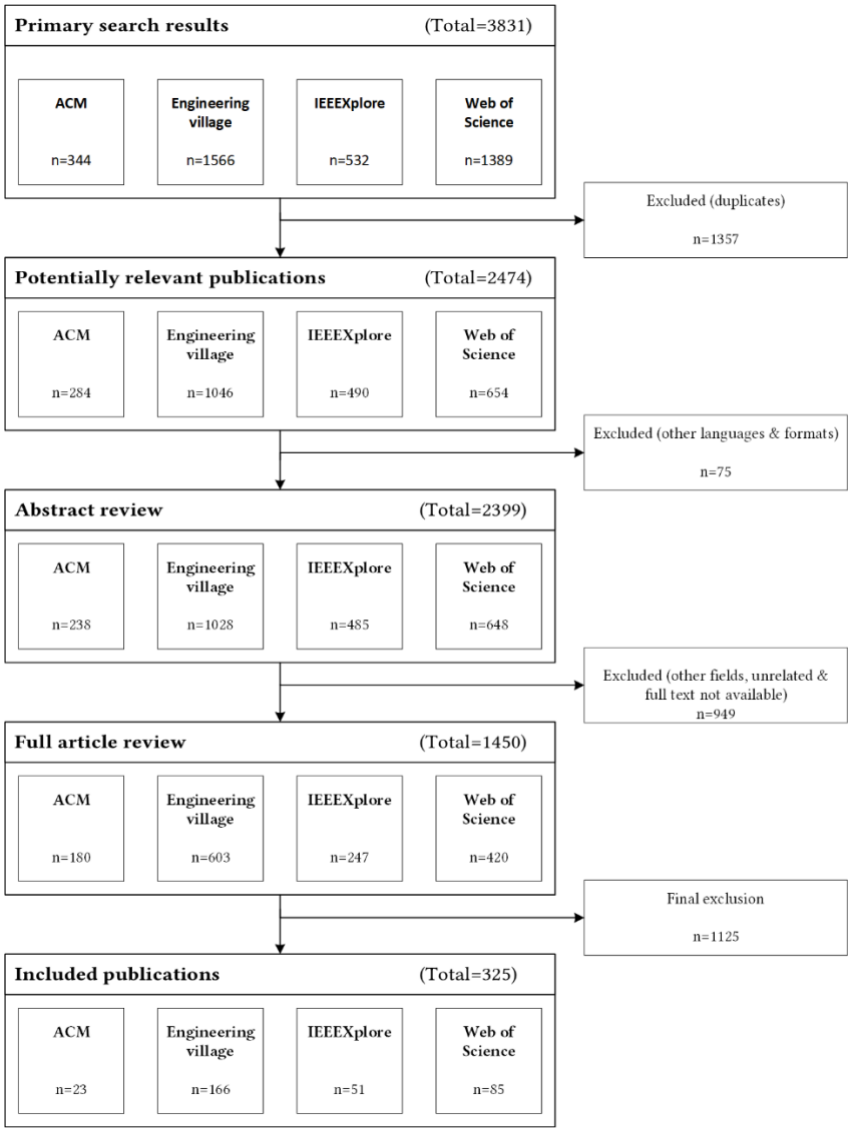

Figure 1- SLR flow chart

Fourth, the full texts of the 1450 remaining papers were downloaded for further analysis. By applying the selection criteria, 1125 papers were excluded (e.g., subjective tools not applied; evaluation done by an observer; only think aloud or interview was used, only physiological or performance measures used; mentioned UX but evaluated usability or technology acceptance; did not mention the dimensions used for the evaluation of UX). The process yielded a corpus of 325 papers, 310 of which were UX empirical studies, and 15 were just focused on method, model, and tool development without empirical data. The complete list of 325 articles reviewed is available in the supplemental material section on the Journal's website.

3.3 Grouping of UX dimensions

The first author investigated the UX tools used in the selected studies and extracted their dimensions to determine which UX dimensions were covered, making a list of 324 UX dimensions. Then, two cognitive ergonomics PhD candidates consolidated the dimensions that had the same concept but different names, such as adaptability and adaptivity. These dimensions highlight the degree to which a product can be tailored to meet the needs of new users or conditions, which is also similar to the concept of flexibility. There are also UX dimensions such as likeability and practicality (Ceccacci et al., 2016) that are used interchangeably in the literature, both of which are concerned with the satisfaction of the user with achieving the pragmatic goals of interacting with a product. Next, a full professor with 40 years of experience in UX research, joined the team for the classification of UX dimensions during two online meetings. The classification was based on the work of Robert (Robert, 2014) in which 8 main dimensions were identified; functional, usability, informational, physical characteristics, sensory, cognitive, psychological, social, and physical (user-related). The odd number of subject matter experts helped to break the tie in case of disagreement. It is important to acknowledge that the grouping of UX dimensions can vary among different authors as some categories may overlap. In this study, the final classification included 13 main dimensions as presented in the results section.

4 RESULTS

This section presents the analysis of the 325 papers selected, pointing out the year of publication, type of product evaluated, field of use, study type, evaluation time, duration of interaction, types of collected data, data collection tools and methods, and the dimensions of UX studied.

4.1 Year and country of publication

The number of publications per year addressing UX dimensions and subjective evaluation tools that met our criteria for the SRL has shown a steep increase since 2017 (**Error! Reference source not found.**). Note that results from 2021 are not representative of the whole year since the search considered papers published until April 2021. Conference papers amounted to 235 of the selected papers with the remaining 90 papers being published in journals.

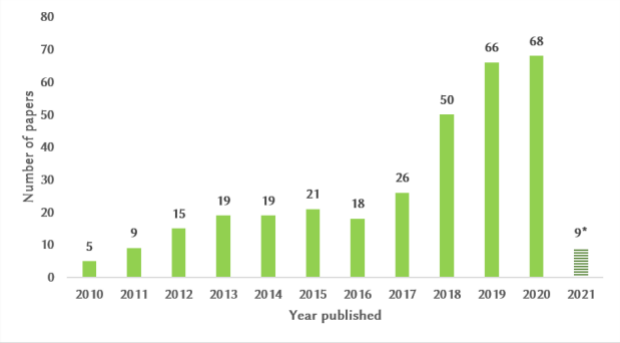

Figure 2- Distribution of the included UX publications per year (n=325) (*2021 papers are incomplete)

The distribution of publications per country was determined based on the affiliation of the first author. This SLR covers publications from 47 countries among which those with more than 5 papers are shown in **Error! Reference source not found.**. Germany, home of pioneering UX evaluation tools like AttrakDiff (Hassenzahl et al., 2003) and UEQ (Laugwitz

et al., 2008), had the greatest number of publications on the subject, followed by two Asian countries. Similarly, among continents Europe had the greatest number of papers with 183, followed by Asia with 89 publications.

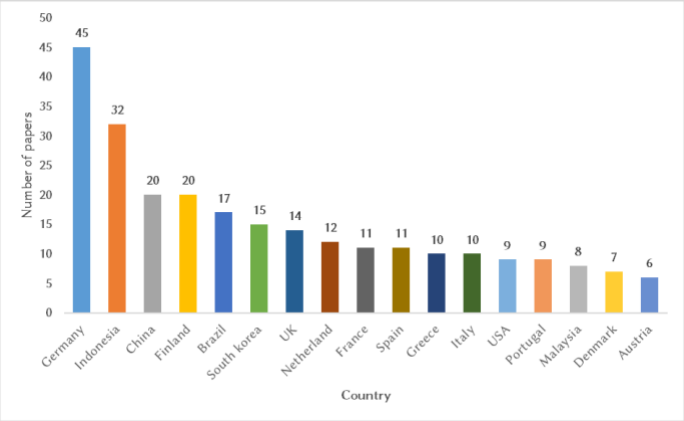

Figure 3- Distribution of the included UX publications per country (n=325)

4.2 Evaluated products

The most frequent type of products evaluated with subjective assessment tools (Table 1) were software applications such as mobile apps, computer software, and digital games, and accounted for 49.7%. The term "system" in the table corresponds to a combination of software and hardware, such as VR training systems (Yue et al., 2016), collaborative robots (Rossato et al., 2021), and multimodal tools for presentation (Schneider et al., 2015). The group "Other" includes products like virtual assistants (Klein et al., 2020), spine posture monitor wearable instruments (Cajamarca et al., 2017), and Brain Computer Interaction (BCI) interfaces (Lorenz et al., 2014), to name a few. In some of the studies more than one type of product was evaluated, such that the total number of products evaluated amounted to 332.

Table 1- Number of evaluated products in the SLR (n=332)

Product	Frequency	Percentage
Software application	165	49.7
System	67	20.2
Website	44	13.3
Other	56	16.8

Overall, classifying the products into two main groups of software and hardware highlights the dominance of former (Table 2).

Table 2- Number of product types in the SLR (n=332)

Product type	Frequency	Percentage
Software	236	71.1
Hardware	11	3.3
Both	85	25.6

In the studies, users were required to evaluate their UX with a prototype (low or high fidelity) or with a fully functional and finished product, depending on the stage of development and the goals of the researchers. Interacting with the finished

product enhances the reliability of evaluation results for some UX dimensions such as aesthetics. Results in Table 3 show that the majority of UX studies evaluated finished products.

Table 3- Number of studies per stage of development of evaluated products (n=332)

Stage of development	Frequency	Percentage
Finished product	240	72.3
Prototype	86	25.9
Both	6	1.8

4.3 Field of use

Bargas-Avilla and Hornbaek (Bargas-Avila & Hornbaek, 2011) classified products into leisure, work or mixed, but UX has been used in a variety of fields. In this study, we grouped them into entertainment (e.g., games), learning & education (e.g., virtual learning environments (Braun et al., 2020)), health & sport (e.g., fall assessment tool (Nawaz et al., 2015)), work & training (e.g., VR aeronautical training app (Sagnier et al., 2020)), information platforms (e.g., digital newspaper (Laine & Leppnen, 2016)), tourism & museum (e.g., digital multimedia interaction(Pretto et al., 2020)), shopping & e-marketplace (e.g., e-commerce website (Bozzi & Mont'Alvao, 2020)), and others (e.g., intelligent elevator system (Ge et al., 2020)) as presented in Table 4. The results show that UX studies are no longer limited to leisure products, but rather have expanded to other fields such as new technologies like AR and VR, which have broadened users' experiences.

Table 4- Number of papers per field of use in the SLR (n=310)

Field of use	Frequency	Percentage
Entertainment	59	19.0
Learning & Education	58	18.7
Health & sport	31	10.0
Work & Training	22	7.1
Information platforms	14	4.6
Tourism & museum	13	4.2
Shopping & e-marketplace	11	3.5
Others	102	32.9

4.4 Study type

Depending on the product, stage of development, cost, and other considerations, the UX evaluation may be conducted in the field, the laboratory, both, and online. Table 5 shows that more than half (51.8 %) of the studies were conducted in a laboratory-setting. Experiments that require specific conditions or use early prototypes are examples of laboratory-based evaluation studies (e.g., head-mounted display integrated with a pulley system to simulate the forces on the user's face in a VR game) (Chang et al., 2018). Field studies represented 20.2% of the studies reviewed and included, for instance, the evaluation of a personal breathalyzer for alcohol consumption by college students over a period of two weeks (Min et al., 2020) or an AR app in a museum (Hammady et al., 2018).

Table 5- Number of studies per study types in the SLR (n=332)

Study type	Frequency	Percentage
Laboratory	172	51.8
Field	67	20.2
Online	29	8.7

Study type	Frequency	Percentage
Both	14	4.2
Not specified	50	15.1

4.5 Evaluation time

UX can be evaluated at different points in time. Anticipated UX is evaluated before using a product, momentary UX is recorded during its use, episodic UX is measured after its use, and cumulative UX considers multiple durations of use (Roto et al., 2011). Table 6 shows that most studies evaluated UX after the interaction with the product. Questionnaires, rating scales, interviews, and pictorial measures are subjective evaluation tools used after interaction with a product, whereas physiological methods like EEG[9], HR[10], EDA[11] or eye tracking are used during the interaction. Because the focus of this SLR was on subjective evaluation tools and methods, we expected to find more studies with UX evaluations done after user interaction with the product. Moreover, it is essential to consider that this SLR excluded studies involving anticipated or imaginary UX, which may have implications when interpreting these results.

Table 6- Number of studies per evaluation time (n=332)

Evaluation time	Frequency	Percentage
After the interaction	271	81.6
During and after the interaction	40	12.0
Before and after the interaction	19	5.7
Before, during, and after the interaction	2	0.6

4.6 Duration of interaction

UX is dynamic and it evolves with time (Robert, 2014). Therefore, it is important to know how long a user has been interacting with a product before evaluating the associated UX. In Table 7, the term “short” refers to an interaction lasting less than a couple of hours, “long” refers to duration of use that range from days to months, and “cumulative” refers to products owned by users and that have been used regularly over long periods. Most studies reviewed (69.9%) evaluated UX after less than a couple of hours of interaction.

Table 7- Number of studies per duration of interaction (n=332)

Duration of interaction	Frequency	Percentage
Short (minutes to hours)	232	69.9
Long (days to months)	36	10.8
Cumulative (regular use over long periods)	27	8.1
Short & long	4	1.2
Not available	33	9.9

4.7 Types of interaction

In UX evaluation studies, users are either free to interact with a product or are required to complete a set of specific tasks. Free interaction allows users to familiarize themselves with a product and reflects the overall UX, whereas performing a set of specific tasks better captures their experience with different parts of the product. Measuring user performance in a

[9] Electroencephalography
[10] Heart rate
[11] Electrodermal activity

specific task set, having limited time for the evaluation, and the stage of development of the product (i.e., final product or prototype) are among factors that researchers and practitioners need to consider when deciding on the type of interaction. Surprisingly, we found that both categories were equally represented in the studies reviewed (Table 8).

Table 8- Number of studies per type of interaction (n=332)

Type of interaction	Frequency	Percentage
Task set	154	46.4
Free	140	42.2
Both	20	6.0
Not available	18	5.4

4.8 Types of data collected

There are two types of data collected in the publications reviewed: qualitative and quantitative. While the former can provide more in-depth information about an experience, the latter can usually be collected in a shorter time. Table 9 shows that most studies used only quantitative data (56.1%) or a combination of both quantitative and qualitative data (42.6%).

Table 9- Number of papers per type of collected data (n=310)

Type of data collected	Frequency	Percentage
Quantitative	174	56.1
Qualitative	4	1.3
Both	132	42.6

4.9 Data collection methods

Table 10 shows the methods used to collect subjective data on UX and their frequency. As expected, questionnaires and rating scales have been used more than any other methods. The other methods used were interview, think aloud, pictorial (e.g., SAM[12], PrEmo), drawing (e.g., iScale, UX curve), writing (e.g., sentence completion, diary), card and board (e.g., MAX[13], reaction cards) and tactile (e.g., SEI[14], TACTUX[15]).

Table 10- UX evaluation methods used in the studies covered by this SLR (n=594)

Data collection method	Frequency	Percentage
Questionnaire/Scale	426	71.7
Interview	72	12.1
Think-aloud	38	6.4
Pictorial	30	5.1
Drawing	11	1.9
Writing	9	1.5
Card & Board	6	1.0
Tactile	2	0.3

[12] Self-Assessment Manikin
[13] Method for the Assessment of eXperience
[14] Sensual Evaluation Instrument
[15] Tactile user experience assessment board

4.10 Subjective evaluation tools in UX studies

In our review, we found 104 different tools used separately or in combination with others to measure UX and allotted them to two categories based on the UX dimensions they measured. You can find an extract of these tools in Table 11. The first category includes tools that evaluate multiple dimensions of UX within a single questionnaire (e.g., AttrakDiff, UEQ, and meCUE). The second category includes tools that target a specific dimension of UX like usability (e.g., SUS[16], CSUQ[17]), emotion (e.g., SAM, PANAS[18]), engagement (e.g., UES[19], GEQ[20]), presence (e.g., PQ[21], SUS[22]), etc. Given the multidimensionality of UX, the use of a combination of these questionnaires appears appropriate.

UEQ has been used more than any other UX evaluation tools, followed by AttrakDiff, another multidimensional UX questionnaire (see Table 12). Among dimension-specific tools, usability was measured most often with SUS, emotion with SAM, workload with NASA-TLX[23] and simulator sickness with SSQ[24].

Table 11- List of tools used in UX studies per UX dimension or subject

Dimension/subject	Tool
Multiple dimensions	UEQ, UEQs, UEQ+, AttrakDiff, meCUE, meCUE2.0, iScale, UX Curve, MAX, UXSC, UXS, SUXES, MUX, sMUX, HED/UT, Bosch UX tool
Usability	SUS, CSUQ, QUIS, PSSUQ, MIPVA-U, NPS, SGUS, SEQ, USE
Flow	FSS, FKS, Flow4D16
Presence	ITC-SOPI, PQ, iPQ, SUS, EVEQ-GP
Emotion	SAM, 3E, 3E*, PrEmo, PANAS, I-PANAS-SF, Geneva Emotion Wheel, EmoCards, Emoticon, Emoti-SAM
Engagement	GEQ, UES, UES-SF
Workload	NASA-TLX, DALI, SMEQ, SEA
Game	CEGEQ, GEQ, EGameFlow, PGQ, GPQ, GUESS, PENS, MEEGA+
Simulator sickness	FMS, SSQ, MSAQ
AR-VR	VRNQ, UX in IVE, VRLEQ
Others	PPA, SASSI, SUISQ, SEI, VisAWI, INTUI, Reaction cards, comfort scale, MIPVA-U, VOF, Fun toolkit, CAS, Godspeed questionnaire, IMI, PENS, UNeeQ, SGUS, UX needs scale.

Table 12- Most frequently used tools in UX studies covered by this SLR

Evaluation tool	Frequency
UEQ, UEQ-S, UEQ+	85
AttrakDiff	47
SUS	43
NASA-TLX	20
SAM	14
SSQ	9

[16] System Usability Scale
[17] Computer System Usability Questionnaire
[18] Positive and Negative Affect Scale
[19] User Engagement Scale
[20] Game Engagement Questionnaire
[21] Presence Questionnaire
[22] Slater-Usoh-Steed Questionnaire
[23] NASA Task Load Index
[24] Simulator sickness questionnaire

Evaluation tool	Frequency
meCUE	8
QUIS	8

Table 13 lists 43 UX evaluation tools that have been developed between 2010 and 2021. They are either case-specific or generally applicable tools. Some of them were developed from the ground up, while others were modifications of previous tools.

Table 13- Subjective UX evaluation tools identified in the SLR (2010-2021)

UX tool	Year	Field
User experience questionnaire for remote lab (UXQ4RL) (Cuadros et al., 2021)	2021	Education (Remote Lab)
User experience questionnaire for intraoperative video capture technology (Saun & Grantcharov, 2021)	2021	Health (Interoperative camera)
Immersive virtual reality user experience questionnaire (IVRUX) (Barbot & Kaufman, 2020)	2020	AR-VR
Virtual reality locomotion experience questionnaire (VRLEQ) (Boletsis, 2020)	2020	AR-VR
User Experience Questionnaire plus for voice assistants (UEQ+) (Klein et al., 2020)	2020	Others (Voice Assistant)
User experience framework for education games questionnaire (EDUGXQ) (Nagalingam et al., 2020)	2020	Education (Educational game)
Questionnaire for technology-enhanced interaction with cultural heritage (Pretto et al., 2020)	2020	Museum
Questionnaire for smart TV UX (Jang & Yi, 2019)	2019	Entertainment (Smart TV)
Formation, apprenant, systeme, enseignant relation learner experience (FASER LX) (Safsouf et al., 2019)	2019	Education
Instrument to evaluate user experience in virtual reality serious games (Ormeño et al., 2019)	2019	AR-VR (serious game)
HaBuT (happiness, burden, trust) instrument to measure user experience (Karunakaran & Brorson, 2019)	2019	Other (Content platform)
Questionnaire for the evaluation of serious games (Moizer et al., 2019)	2019	Work (serious game)
Tangible kit to evaluate UX of older adults (Aestimo) (Rodriguez et al., 2019)	2019	General tool (For elderly)
User experience questionnaire plus (UEQ+) (Schrepp & Thomaschewski, 2019)	2019	General tool
Mobile user experience (MUX), short form of mobile user experience (sMUX) (Wilson & Djamasbi, 2019)	2019	Others (Mobile devices)
Questionnaire for the evaluation of VR glasses system (Yu et al., 2019)	2019	AR-VR (VR glasses system)
Short user experience questionnaire (Alberola et al., 2018)	2018	General tool
Modular evaluation of key components of user experience 2.0 (Minge & Thuring, 2018)	2018	General tool
Questionnaire for the evaluation of social robot (Nielsen et al., 2018)	2018	Others (Social robot)
Questionnaire for the evaluation of Internet of things ecosystem (Orehovaki et al., 2018)	2018	Others (IoT ecosystem)
Questionnaire for the evaluation of home appliances (Park et al., 2018)	2018	Others (Home appliances)
Questionnaire for the evaluation of mobile application's interface (Yang et al., 2018)	2018	Others (Mobile app's interface)
Questionnaire for the evaluation of mobile app (Krawczyk et al., 2017)	2017	Education
User experience scorecard (UXSC), User experience scale (UXS) (Lee & Ivory, 2017)	2017	General tool
Modular evaluation of key components of user experience (meCUE) (Minge et al., 2017)	2017	General tool

UX tool	Year	Field
Quantified user experience (QUX) (Lachner et al., 2016)	2016	Others (UX for organizations)
UX in Immersive virtual environments questionnaire (UX in IVE) (Tcha-Tokey et al., 2016)	2016	AR-VR
Evaluating the user experience of interactive digital narrative (Roth & Koenitz, 2016)	2016	Entertainment (IDN)
Questionnaire for the evaluation of newspapers (Laine & Leppnen, 2016)	2016	Others (Digital newspaper)
Method for the assessment of experience (MAX) (Cavalcante et al., 2015)	2015	General tool
Questionnaire for the evaluation of home appliances (Macedo & Marcio Silva, 2014)	2014	Others (Home appliances)
Tactile user experience assessment board (TACTUX) (Regal et al., 2014)	2014	General tool
Interactive TV user experience questionnaire (ITVUX) (Bernhaupt & Pirker, 2013)	2013	Entertainment (Interactive TV)
Questionnaire for the evaluation of mobile phone and services (Park et al., 2013)	2013	Others (Mobile phones)
Chinese user experience questionnaire (Liu et al., 2013)	2013	General tool)
The user needs questionnaire (UNeeQ) (Sonnleitner et al., 2013)	2013	General tool
Questionnaire for the evaluation in an automotive context (Korber et al., 2013)	2013	Others (Car)
Questionnaire for the evaluation of location-based applications (Zhuo et al., 2013)	2013	Others (Location-based app)
Questionnaire for the evaluation of industrial robots (Buchner et al., 2012)	2012	Work (Industrial robots)
iScale (Kujala et al., 2011)	2012	General tool
UX Curve (Kujala et al., 2011)	2011	General tool
Questionnaire for the evaluation of brain-computer interaction gaming (Van De Laar et al., 2011)	2010	Entertainment (Gaming)

UX models, method, and frameworks have also been proposed in this period, building the foundation for the development of more UX evaluation tool (Table 14).

Table 14- UX model, methods, frameworks identified in the SLR (2010-2021)

UX model, method, framework	Year	Field
User experience evaluation index of augmented reality applications (Wang & Lv, 2020)	2020	AR-VR
User experience evaluation model of dynamic mathematics software (Wang et al., 2021)	2020	Education
User experience evaluation model of computer input devices (Huang et al., 2019)	2019	Others (Computer input device)
User experience evaluation model of smart jewelry (Lin et al., 2019)	2019	Others (Smar jewelry)
User experience evaluation method of 3D websites (Liu et al., 2018)	2018	Others (3D website)
User experience evaluation framework of e-moderation (Van Staden et al., 2015)	2015	Education (eModeration)
Empirical model of the user experience (Ariza & Maya, 2014)	2014	Others (Headphone)
Assessment model of user experience of smart mobile phones (Wan & Zhu, 2013)	2013	Others (Mobile phones)

4.11 UX dimensions

UX dimensions covered by evaluation tools and the studies we reviewed varied greatly, with some focused only on usability or task-oriented aspects, whereas others included hedonic and affective dimensions. Table 15 shows a grouping

of UX dimensions in 13 main dimensions with some examples of components for each one. The number of times each dimension was present in the 325 studies is also indicated. The most frequent dimensions were usability, hedonic, utility, and sensory, which are all included in the UEQ and AttrakDiff questionnaires, the most frequently used tools. Surprisingly, the least frequent UX dimensions were the informational, social, physical, and cognitive dimensions. UX tools evaluating five or more dimensions are shown in

Usability and utility are the two pragmatic dimensions of UX (Konstantakis et al., 2017). **Usability** deals with ease of use and efficiency of a product (Toomim et al., 2011), while **utility** focuses on its function. Among the usability sub-dimensions, ease of use, learnability, perspicuity, memorability, and intuitive usage are concerned with how easy a product is to use and reuse. Familiarity, predictability, and consistency are sub-dimensions concerned with the navigation through a product. The other usability sub-dimensions are efficiency and customization, which speed up user interaction; and error tolerance and feedback, which prevent or resolve possible problems. The sub-dimensions of utility contribute to the functionality of a product, including effectiveness, reliability, availability, stability, safety, durability, scalability, and interoperability.

Hedonic dimension is the non-task-related aspect of interaction with a product that differentiates UX from the goal-oriented concept of usability. In our categorization, it includes sub-dimensions such as novelty, fun, pleasure, enjoyment, stimulation, and evocation, all intertwined with the desirable aspects of using a product. Beauty is among the sub-dimensions that we have separated from the hedonic dimension to cover it under **sensory** dimension. This dimension encompasses the ways in which products are perceived through different senses. A product's visual aesthetics, its sounds and noises, and the tactile experience during an interaction are included in the sensory dimension (Robert, 2014). Depending on the UX model, **emotion** is considered as a UX dimension (e.g., CUE model (Thüring & Mahlke, 2007)) or a consequence of the interaction (e.g., UX model of Hassenzahl (Hassenzahl, 2003)). In this study, emotion is regarded as a UX dimension including the positive and negative emotions that users experience during or after an interaction with a product.

Recent years have seen an increase in the importance of content as a result of the availability of information. The quality, quantity, and trustworthiness of the information presented to users in different formats are evaluated under the **informational** dimension. Using simple communication services like calling or texting, sharing photos on social networks, or challenging friends on a fitness app, social features are growing in different products and software. As a result, we have defined the **social** dimension to include sub-dimensions such as sociability, social acceptance, social relatedness, and conformity. Another aspect of the social dimension is the collaboration and cooperation fostered by social interactions (e.g., (Moosa et al., 2020; Shu-Hui et al., 2018)).

In addition to gaming consoles and personal computers, smartphones with high performance and efficient processors are attracting more users to play games. Ideally, a game should entertain its players by immersing them in a virtual environment, keeping their attention through a compelling story and exciting gameplay elements, and testing their skills through reasonable challenges. We cover these aspects under the **engagement** dimension. Its sub-dimensions are immersion, presence, flow, absorption, attention, concentration, and involvement. Moreover, serious games have been introduced to be used for education, training, and skill development purposes (De Lima et al., 2015). In relation to this, the **cognitive** dimension encompasses aspects of interaction with a product that involve learning, knowledge creation, and skill development (Robert, 2014) including sub-dimensions such as learning performance, learning helpfulness, and cognition effectiveness.

The physical characteristic of a product is another important UX dimension that includes aspects such as weight, shape, and dimensions. Wearability, portability, physical suitability, invasiveness, and manageability are its related sub-

dimensions. The use of physical and software products can have some impacts on users. Visual discomfort, disorientation, and problems with returning to reality are examples of the effects on the body when using augmented and virtual reality (AR and VR) headsets. We categorized sub-dimensions such as fatigue, workload, tiredness, mental and physical stress, discomfort, and disorientation under the UX dimension called **impact on body**.

We grouped the sub-dimensions related to the consequences of interaction with a product in the **judgement** dimension. It includes the intention to use, the willingness to recommend a product to others, loyalty, endurability, and trust. The last dimension of our categorization is the **overall impression**. It addresses the question of whether a product yields a positive or negative experience. This dimension can be evaluated with a single question, like in the meCUE questionnaire or measured with multiple items, like the attractiveness dimension in the UEQ and AttrakDiff questionnaires. We acknowledge that specific application fields or products require custom UX sub-dimensions, such as naturalness for smart homes, social actorship for embodied spoken dialogue systems, and effectance and suspense for interactive digital narratives. We included these field-specific sub-dimensions in the **others** categories.

Table 16. The complete list of UX tools and their dimensions can be found in Appendix 2.

Table 15- UX dimensions and included sub-dimensions in the 325 studies covered by this SRL

UX dimension	Components of the dimension	No.	Percentage
Usability	Ease of use, learnability, controllability, error tolerance, efficiency, etc.	283	87.1
Hedonic	Stimulation, identification, enjoyment, fun, novelty, desirability, etc.	271	83.4
Utility	Usefulness, helpfulness, stability, credible, practicality, reliability, etc.	222	68.3
Sensory	Visual (aesthetic), haptics, acoustics, beauty, etc.	191	58.8
Overall impression	Attractiveness, goodness, overall user experience	167	51.4
Judgment	Intention to use, recommending to others, endurability, loyalty, etc.	87	26.8
Emotion	Positive emotion, negative emotion, valence, arousal	73	22.5
Engagement	Immersion, presence, flow, attention, absorption, involvement, etc.	70	21.5
Impact on body	Discomfort (comfort), workload, fatigue, sickness, headache, etc.	64	19.7
Informational	Content quality, content quantity, information structure, readability, etc.	39	12.0
Social	Social interaction, sociability, social acceptance, social actorship, etc.	34	10.5
Physical characteristic	Weight, shape, wearability, portability, delicacy, manageability, etc.	19	5.8
Cognitive	Learning, cognition effectiveness, learning performance, etc.	16	4.9
Others	Ownership, pride, naturalness, exploration, etc.	63	19.4

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25 Component of User Experience model

Table 16- UX tools with the most frequent dimensions evaluated

UX tool	Usability	Utility	Emotion	Hedonic	Engagement	Social	Informational	Sensory	Impact on body	Judgment	Physical	Cognitive	Overall UX	Others	Total
MEEGA+	✓	-	-	✓	✓	✓	✓	✓	-	✓	-	✓	✓	✓	10
UX in IVE	✓	✓	✓	✓	✓	-	-	✓	✓	✓	-	-	-	✓	9
GUESS	✓	-	-	✓	✓	✓	-	✓	-	✓	-	-	-	✓	7
GEQ	-	-	✓	-	✓	✓	-	✓	✓	-	-	-	✓	✓	7
meCUE	✓	✓	✓	✓	-	-	-	✓	-	✓	-	-	✓	-	7
Park (2013)	✓	✓	-	✓	-	✓	✓	✓	-	-	✓	-	-	-	7
SASSI	✓	✓	✓	✓	-	-	-	-	✓	✓	-	-	-	-	6
UEQ+	✓	✓	-	✓	-	-	✓	✓	-	-	-	-	✓	-	6
EGameFlow	✓	-	-	-	✓	✓	-	-	✓	-	-	✓	-	✓	6
EDUGXQ	✓	✓	-	✓	✓	-	-	-	-	-	-	✓	-	✓	6
AttrakDiff	✓	✓	-	✓	-	-	-	✓	-	-	-	-	✓	-	5
CEGEQ	✓	-	-	✓	-	-	-	✓	-	✓	-	-	-	✓	5
QUIS	✓	-	-	✓	-	-	✓	✓	-	-	-	-	✓	-	5
UEQ	✓	✓	-	✓	-	-	-	✓	-	-	-	-	✓	-	5
UES	✓	-	-	✓	✓	-	-	✓	-	✓	-	-	-	-	5
UXQ4RL	✓	✓	-	✓	✓	-	-	-	-	-	-	✓	-	-	5
VRNQ	-	-	-	✓	✓	-	-	✓	✓	-	-	-	-	✓	5

5 DISCUSSION

This SLR provided the state of the art on UX subjective evaluation studies published from 2010 to 2021. This discussion starts with a general overview of the products and user interactions evaluated in the studies reviewed. Then, we discuss the UX tools and methods that were used, followed by the UX dimensions that were found to be less frequently covered in UX tools. Finally, we highlight the importance of technology in improving UX evaluations and conclude with the main takeaways.

5.1 Landscape of UX studies

This SLR found that half of the UX studies were from Europe, and as well, out of the 43 new UX evaluation tools identified more than half (25) originated in Europe. Thus, Europe is the main contributor to UX studies with Germany and Finland being the most influential countries. In Asia, Indonesia had the highest number of papers, but they mainly used previously developed tools (72% used UEQ). China showed growth in this field by developing and applying various tools in different fields, and by providing the highest number of UX research studies on emerging technologies. It is worth noting that the distribution of the country of publication was determined based on the affiliation of the first author in this SLR. In terms of publication venues, our findings support Hassenzahl and Tractinsky's (Hassenzahl & Tractinsky, 2006) observation, as a higher percentage of UX studies (72%) are being published in conferences as opposed to journals.

UX studies cover a wide spectrum of products, such as an industrial robotic arm, a fall assessment tool, a museum portal, a virtual dressing room, a classroom training simulator, games, and more. Consequent with the rising use of mobile

devices globally, mobile applications had the highest number of UX evaluation studies. This trend can be expected to grow as handheld devices become more capable of running power-intensive applications and peripheral devices like AR-VR headsets, which currently require computers. Robinson and colleagues claimed that UX studies are falling behind emerging topics like AR/VR, gaming and mobile technologies (Robinson et al., 2017). This SLR found that this is no longer the case as, for instance, AR/VR accounted for 18.3% of all studies compared to 1.6% (Robinson et al., 2017) and 2% (Pettersson et al., 2018) in previous SLRs.

UX evaluations were conducted on final products in 72.3% of the studies. Prototypes evaluations went from 10.3% in the SLR of Robinson et al. (Robinson et al., 2017) to 25.9% (this SLR), with an increase in the number of studies from 2018 onwards. Compared to prototypes, final products provide the user with a complete set of features and characteristics that provides a comprehensive and multi-faceted UX. However, the researchers' concerns about a lack of UX studies in the early stages of product development remain (Vermeeren et al., 2010). However, “mixed prototype” or “augmented prototyping” has emerged recently as a solution to simulate a final product using AR technology by projecting an artificial layer on the product physical model for usability testing purposes (Faust et al., 2019). Moreover, using VR was also proposed to detect and correct design flaws faster than with physical prototypes and also to reduce their associated costs. However, touch and feel are lacking and have yet to be integrated to these new technologies (Freitas et al., 2020).

All of the studies reviewed conducted UX evaluations after the interaction of the user with the product, and only 18.4% conducted an evaluation before and/or during the interaction as well. In the before-and-after evaluation studies, user expectations toward the expected use of the product were measured either by using common UX questionnaires like AttrakDiff (Weiss & Willkomm, 2013) or specific UX questionnaires like SUXES (e.g., (Vuorio et al., 2018)) that specifically include expectation measurement. When interacting with children, fun toolkits were used to collect changes in their expectations before and after the interaction with a product, such as the Smileyometer, Again-Again table, Funometer, and Fun sorter tools. Just as Pettersson et al. (Pettersson et al., 2018), we found few studies taking into account expectation and its relation to UX, and as reported by Bargas-Avila and Hornback (Bargas-Avila & Hornbaek, 2011) we noted an overall lack of UX measurement before interaction. It is worth keeping in mind that when interpreting the results, it is essential to note that this SLR excluded papers focusing only on the anticipated use of a product.

The time that users spent with a product before UX evaluation was short (i.e., from a few minutes to a couple of hours) in 69.9% of the studies reviewed. Laboratory studies where users often have a limited time to interact with a product were more numerous than field studies. However, user-centric innovation environments like Living Lab have emerged, aiming to actively involve users in the product development process within real-life contexts (Alavesa et al., 2018), which can thus increase the interaction time of users with products.

However, new user-centric methodologies such as Living Lab have been introduced to involve users more in the development process of a product in real life contexts.

5.2 Emerging trends in UX evaluation tools

Similar to Bargas-Avila and Hornback (Bargas-Avila & Hornbaek, 2011), no studies covering a product life cycle were found in this SLR. But longitudinal studies lasting up to 6 months to measure UX changes over time have been conducted throughout the last decade (e.g.,(Hart & Sutcliffe, 2019; Kim et al., 2015; Marti & Iacono, 2017; Sahar et al., 2014)). Some of the most famous long-term UX evaluation tools (UX curve (Kujala et al., 2011) and iScale (Karapanos et al., 2012)) were developed in this period, as well as modified versions to address specific limitations of these original tools. For instance, MemoLine modified the UX curve to facilitate its use with children (Vissers et al., 2013), while DrawUX was developed to collect UX data remotely (Varsaluoma & Kentta, 2012). UX graph was introduced as a revised version of

UX curve, to capture in a single satisfaction graph, events occurring in different phases from the user's expectations before purchasing a product to the anticipation of future use (Kurosu et al., 2016). Finally, the Experience Recollection Method (ERM) removed the exact timeline of the experience to reflect the fact that episodic memory tends to fade with time, which in turn facilitated the use of the tool (Kurosu et al., 2018). In addition to new tools, new approaches like the cross-sequential approach for data collection was presented to decrease the evaluation time by collecting UX data from different groups of users each being at a different phase of a product's usage (Kujala et al., 2019).

The most common methods used for gathering qualitative data from users were interview and think-aloud. Concurrent think aloud (CTA) is used during user interaction with a product, whereas retrospective think aloud (RTA) and interview are used after the interaction. The laddering technique and the valence method were used in UX studies like (Brennand et al., 2019; Burmester et al., 2010) to improve the quality of interviews. The laddering technique starts the interview by talking about the product features and digs deeper into the subjective reasons behind the user's perceived importance of the features by repeatedly asking the "why" question (Brennand et al., 2019). In the valence method, users mark their positive and negative feelings during the use of a product and discuss those experiences with the researcher in a retrospective interview, enabling them to uncover underlying meanings and needs (Burmester et al., 2010).

Among other qualitative methods, focus groups were used with experts for items development of new UX evaluation tools (e.g., (Minge et al., 2017)), while diaries were used to capture users' long-term experiences with the day reconstruction method (DRM) (e.g., (Kim et al., 2015)) or the experience sampling method (ESM) (e.g., (Colombo & Landoni, 2014)). Methods used in other domains found their way into the UX field and were tested to be used in conjunction with current UX evaluation tools and methods. For instance, Kujala and her colleagues (Kujala et al., 2014) introduced the sentence completion method to the field of UX by conducting case studies comparing sentence completion to AttrakDiff. They found sentence completion to be less culturally biased compared to rating scales and easier to analyze compared to interviews. Similarly, co-discovery as a user testing method, in which two users interact with a product and freely talk about it, was used in the context of UX to elicit invaluable findings regarding user's perception, emotions and reactions (Rusu et al., 2017).

This SLR identified all of the evaluation tools that were used in the UX studies as well as the new ones developed during 2010-2021. UX evaluation tools can be categorized either as general tools, that can be used with any product, or domain-specific tools that were developed for a particular domain. As opposed to Bargas-Avilla and Hornbaek (Bargas-Avila & Hornbaek, 2011) who reported that UX researchers would rather develop their own questionnaires than use the validated tools, we found that established questionnaires for specific UX dimensions were being largely adopted since their use improves robustness of the findings and allows comparison of the results between studies.

Among the general tools, meCUE is based on the CUE model, and was first introduced in German (Minge et al., 2014) and then translated into English (Minge et al., 2016). It has a modular structure comprising 1) product perceptions, 2) emotions, 3) consequences of use, and 4) overall UX modules. The evaluators select the modules that best apply to the UX dimensions they are interested in. meCUE is a validated tool that was compared with other well-known tools like AttrakDiff, UEQ, SAM and PANAS (Minge et al., 2017). A major limitation of meCUE is that it is unsuitable for business-oriented applications such as an intranet, since users will disregard hedonic dimensions in these (Lallemand & Koenig, 2017). As a result, the second version of the tool (meCUE 2.0) splits the first module of product perceptions into two separate modules: 1) perception of instrumental product qualities and 2) perception of non-instrumental qualities (Minge & Thuring, 2018). Instrumental qualities include pragmatic and functional aspects of a product, while non-instrumental qualities cover hedonic aspects like beauty, status, and commitment (Minge & Thuring, 2018).

The concept of modularity was embraced by the authors of the UEQ questionnaire and resulted in the development of UEQ+, a modular evaluation tool that provides a list of UX dimensions and corresponding evaluation items (Schrepp & Thomaschewski, 2019). Modularity of this tool enables researchers to add more dimensions to UEQ+ depending on the product under study. For instance, Boos and Brau (Boos & Brau, 2017) added two haptic and acoustic UX dimensions for household devices, and Klein et al. (Klein et al., 2020) developed three new dimensions for the UX evaluation of voice assistants.

The belief that more domain-specific tools should be developed has many supporters on the grounds of the fact that standard evaluation tools cannot capture UX dimensions in all domains (Bernhaupt & Pirker, 2013; Darin et al., 2019; Lallemand & Koenig, 2017). This led to the development of new tools for specific products like interactive TV (Bernhaupt & Pirker, 2013), smart TV (Jang & Yi, 2019), home appliances (Macedo & Marcio Silva, 2014; Park et al., 2018), and AR/VR (Barbot & Kaufman, 2020; Tcha-Tokey et al., 2016) to name a few. In addition to these, some current tools were tailored to be used specifically with new products or with new target populations. For instance, the Game Experience Questionnaire (GEQ) was modified to be used with BCI games (Van De Laar et al., 2010), and the Chinese UX questionnaire was developed based on AttrakDiff with the assumption that UX dimensions that are commonly accepted in western cultures might not equally apply to eastern countries. Consequently, a tool with the following three dimensions, stimulation, pragmatic quality and conformity, was developed. “Conformity” was defined as a dimension that shows how popular a product is among friends and how it is well-received by other users (Liu et al., 2013).

A number of UX evaluation tools use physical objects for the evaluation of UX, such as cards and boards. For instance, MAX captures the UX of users in four categories using cards (Cavalcante et al., 2015), while Aestimo uses a tangible interface based on AttrakDiff specifically developed to capture the UX of elderly users. The interface uses tangible and familiar elements like buttons, knobs, and switches to be playful and at the same time increase the understandability of the evaluation process (Rodriguez et al., 2018; Rodriguez et al., 2019). Other tools like TACTUX use tactile properties to assess UX of a product (Regal et al., 2014).

The necessity of triangulating results from different tools and methods in UX evaluation has been established as a best practice in the field (Pettersson et al., 2018). Consequently, the number of studies using multiple and varied tools has increased in the last decade, with 173 studies (55.4%) using two or more tools for their evaluation. Studies using a single tool that covers multiple dimensions (e.g., meCUE, UEQ, AttrakDiff) have also gained attention in recent years.

Technology offers novel ways to collect user feedback when using the UX tools we reviewed. For instance, InteracDiff (Dittrich et al., 2019) implemented an interactive prototype that changes the presentation format of AttrakDiff to make it easier to understand and use for people outside the scientific community. Another example is the development of a pictorial scale called MAM[26] that enables users to remain in the virtual environment for the UX evaluation of AR-VR products (Krüger et al., 2020). Lastly, Meedin & Perera (Meedin & Perera, 2014) developed a crowdsourcing platform for the evaluation of user interface design by gathering users and designers. Using an avatar, the platform asks questions to users and categorizes them in different personas. The designers can then evaluate their products with a target population through the intelligent user experience questionnaire (IUEQ) that is embedded in the platform, and thus generate distinct questionnaires for different types of users.

5.3 Exploring UX dimensions in evaluation tools

This SLR identified more than 300 UX dimensions. We classified them under 13 main dimensions and determined which dimensions were addressed in different UX tools. Our findings uncovered drastic changes regarding the number of

[26] Morph A Mood

dimensions covered in UX studies compared to the results reported by Bargas-Avilla and Hornbaek (Bargas-Avila & Hornbaek, 2011). In their review only 6% of studies evaluated four or more dimensions, whereas 78.8 % of the studies we reviewed covered at least four UX dimensions. Among the general UX tools, meCUE and UEQ+ cover the highest number of dimensions proving that recent UX tools are more comprehensive. As indicated earlier, modular tools enable researchers to modify them according to needs of their study and in the case of UEQ+, adding more dimensions is also possible. The multidimensionality of UX speaks to its flexibility and versatility, however it should be carefully managed as decomposing UX into several dimensions can lead to "dimensionality explosion," with a plethora of dimensions some of which may have no link to established constructs (Bargas-Avila & Hornbaek, 2011), while others measure the same thing but with different names. Recent studies like the one from Raptis et al. (Raptis et al., 2017) examined the relationships between new factors (e.g., coolness) and other UX constructs to prevent further dimensionality increase.

A deliberate choice was made to exclude technology acceptance and usability studies. This decision aimed to maintain a pure focus on UX evaluation. Although technology acceptance models do share some overlap with UX (Distler et al., 2020), their primary focus on the expected UX (Roto, 2007), which occurs without any interaction with the product, fell outside the scope of this study. Considering the intertwined relationship between usability and UX, we included usability studies when they were specifically measured within the context of UX.

Dimensions such as physical characteristics of products, cognitive, social, and informational have been less addressed in the UX studies we reviewed. The fact that software represented the majority of the products evaluated could explain why physical aspects of products were not frequent. Indeed, common UX tools such as AttrakDiff, meCUE and UEQ were originally developed for software products, thus do not include physical characteristics Some of the new tools like MUX and sMUX do take into account the role and impact of hardware on software in UX evaluation (Wilson & Djamasbi, 2019). Raptis and colleagues (Raptis et al., 2014) studied the effect of perceived hedonic quality of mobile devices on the UX evaluation of mobile applications, by comparing two different devices on factors like the style, visual design, age and the construction materials. Their results showed that pragmatic dimensions of mobile applications were affected by these factors (Raptis et al., 2014). Hence, physical characteristics not only impact directly the UX of physical products but also affect indirectly the UX of software products. On this subject, it is worth noting that concepts coming from other disciplines, such as industrial design, influence the overall experience with physical products. Recent work on aesthetic of interaction (Lenz et al., 2014) i.e., what is a good interaction with a physical artifact, is such an example that should make its way into UX evaluation of interactive products.

Another UX aspect that has received less attention in UX studies is the social dimension, which one could look at from three different perspectives. The degree to which a product enables the user to interact with others is one, while the acceptance of a user by others or by him/herself when using or owning a product is another one. The degree to which a product exhibits socially accepted behavior, which applies to robots or voice-based interactive products (e.g., (Skjuve & Brandzaeg, 2019)) is a third one. In this study we focused on the first two perspectives and categorized the UX dimensions accordingly. Among the general UX tools, UEQ and its extensions (i.e., UEQs, UEQ+) did not cover the social dimension, whereas AttrakDiff used only three bipolar items (isolating - connective), (separates me – brings me closer) and (alienating – integrating) mainly focused on the identification aspect of product usage. As for meCUE, it uses a "status" dimension to cover a user's self-image when using a product. The social dimension is better covered in other tools like the social module of GEQ[27] (IJsselsteijn et al., 2013) that evaluates empathy with others, evoked feelings, and behavioral involvement caused by interaction with others. Collaboration and cooperation in social interactions are other facets that were included in recent studies (Moosa et al., 2020; Shu-Hui et al., 2018). There is a need for UX tools or modules that better cover social

[27] Game Experience Questionnaire

dimensions in an era where new social media applications (e.g., Clubhouse, TikTok) and new features to existing products (e.g., bullet screen (Zhang et al., 2020)) are announced daily.

The trustworthiness, quality, quantity, and structure of the information provided by the product are important to the overall UX that we categorized in the informational UX dimension. For instance, UEQ+ included trustworthiness and quality of content (Schrepp & Thomaschewski, 2019), the informativeness dimension was used with mobile devices (Park et al., 2013), and trustworthiness and abundance of content were evaluated in the study of digital newspaper (Laine & Leppnen, 2016). The informational dimension needs more attention now that we have both publishers generated (e.g., Netflix, Disney+, News websites, etc.) and user generated (e.g., YouTube, Instagram, TikTok, etc.) contents.

5.4 Limitations

SLRs have limitations that cannot be completely circumvented. The selection of search terms, databases, inclusion and exclusion criteria do impact the results of the SLRs. We have incorporated four databases to ensure better coverage of UX studies and consulted a librarian specialist to use optimal search strings for each database. However, due to the language barrier, we limited the papers to only English publications.

The findings of this study are derived from a review of scientific papers, and it is important to interpret the results within the context of these studies. For instance, it should be noted that the absence of papers reporting on UX evaluations in the early stages of product design in this SLR does not necessarily imply that such evaluations have not been conducted. The HCI field has experienced a gap between academic researchers and industry practitioners when it comes to implementing academic findings in practical settings and aligning those studies with real-world industry challenges (Gray et al., 2014). This gap is also evident in the area of UX, particularly concerning how to define and evaluate UX (Basri et al., 2016). Notably, there is a scarcity of published evaluation tools and methods developed by industrial partners (Vermeeren et al., 2010).

The grouping of UX dimensions in this study is subject to limitations. It is worth noting that defining clear boundaries between certain UX dimensions can be challenging, leading to potential variations in grouping among different authors. This inherent subjectivity should be considered when interpreting the results.

6 CONCLUSION

In this SLR, we reviewed the subjective UX evaluation tools and the dimensions they included for the period spanning from 2010 to 2021. Results showed the advent of modular tools in recent years and the advantages they bring through their potential to make the evaluation easier by gathering information on different dimensions with a same tool, and by being easy to customize to the particular product under study. We have also highlighted 4 groups of UX dimensions that were addressed less frequently in UX evaluation studies: physical, informational, social and cognitive. Moreover, the current state of UX research regarding the countries with the most contributions to this field, the products evaluated, the evaluation time, the duration of product use before evaluation, the evaluation method, and the evaluation tools were presented to benefit researchers and practitioners alike. We suggest that additional UX evaluation tools should incorporate the mentioned dimensions to enhance the overall UX assessment. Furthermore, exploring whether the modularity trend extends to other disciplines or concepts within the HCI field is also recommended.

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Appendix 1

Search strings of different databases

Engineering village

Table 17- Search fields in Engineering village

Time Frame	Language	Type of document	Search fields
2010-2021	English	Journal article, Conference paper	KY: subject, title, abstract

(((((((((evaluation NEAR/2 UX) OR (evaluating NEAR/2 UX) OR (evaluation NEAR/2 "User experience") OR (evaluating NEAR/2 "User experience") OR (measurement NEAR/2 UX) OR (measuring NEAR/2 UX) OR (measurement NEAR/2 "user experience") OR (measuring NEAR/2 "user experience") OR (tool NEAR/2 UX) OR (tool NEAR/2 "user experience") OR (dimension NEAR/2 UX) OR (component NEAR/2 UX) OR (attribute NEAR/2 UX) OR (aspect NEAR/2 UX) OR (indicator NEAR/2 UX) OR (factor NEAR/ UX) OR (element NEAR/2 UX) OR (dimension NEAR/2 "user experience") OR (component NEAR/2 "user experience") OR (attribute NEAR/2 "user experience") OR (aspect NEAR/2 "user experience") OR (indicator NEAR/2 "user experience") OR (factor NEAR/2 "user experience") OR (element NEAR/2 "user experience") OR (tools NEAR/2 UX) OR (tools NEAR/2 "user experience") OR (dimensions NEAR/2 UX) OR (components NEAR/2 UX) OR (attributes NEAR/2 UX) OR (aspects NEAR/2 UX) OR (indicators NEAR/2 UX) OR (factors NEAR/ UX) OR (elements NEAR/2 UX) OR (dimensions NEAR/2 "user experience") OR (components NEAR/2 "user experience") OR (attributes NEAR/2 "user experience") OR (aspects NEAR/2 "user experience") OR (indicators NEAR/2 "user experience") OR (factors NEAR/2 "user experience") OR (elements NEAR/2 "user experience"))wn KY))) AND (([125] OR [126]) WN DT)))) AND ({English} spanning WN LA))

IEEE Xplore

Table 18- Search fields in IEEE Xplore

Time Frame	Language	Type of document	Search fields
2010-2021	-	Journal article, Conference paper, Early access articles	All

((evaluat* OR measur* OR tool OR dimension OR component OR attribute OR aspect OR indicator OR factor OR element) NEAR/2 ("user experience" OR UX))

Web of Science

Table 19- Search fields in Web of Science

Time Frame	Language	Type of document	Search fields
2010-2021	English	Proceeding paper, Journal, Early access	TS: Title, abstract and keywords

((TS=(("user experience" OR UX) NEAR/2 (evaluat* OR measur* OR tool* OR dimension* OR component* OR attribute* OR aspect* OR indicator* OR factor* OR element*))))

ACM Digital Library

Table 20- Search fields in ACM Digital Library

Time Frame	Language	Type of document	Search fields
2010-2021	-	Journal article, Conference paper	Abstract

[Abstract: recordabstract:] OR [Abstract: "ux evaluation"] OR [Abstract: "evaluating ux"] OR [Abstract: "evaluation of ux"] OR [Abstract: "evaluate ux"] OR [Abstract: "measuring ux"] OR [Abstract: "measurement of ux"] OR [Abstract: "ux measurement"] OR [Abstract: "measure ux"] OR [Abstract: "ux tool"] OR [Abstract: "tool of ux"] OR [Abstract: "user experience evaluation"] OR [Abstract: "evaluating user experience"] OR [Abstract: "evaluation of user experience"] OR [Abstract: "evaluate user experience"] OR [Abstract: "measuring user experience"] OR [Abstract: "measurement of user experience"] OR [Abstract: "user experience measurement"] OR [Abstract: "measure user experience"] OR [Abstract: "user experience tool"] OR [Abstract: "tool of user experience"] OR [Abstract: "ux dimension"] OR [Abstract: "ux aspect"] OR [Abstract: "ux attribute"] OR [Abstract: "ux indicator"] OR [Abstract: "ux component"] OR [Abstract: "ux factor"] OR [Abstract: "ux element"] OR [Abstract: "user experience dimension"] OR [Abstract: "user experience aspect"] OR [Abstract: "user experience attribute"] OR [Abstract: "user experience indicator"] OR [Abstract: "user experience component"] OR [Abstract: "user experience factor"] OR [Abstract: "user experience element"] OR [Abstract: "evaluating the ux"] OR [Abstract: "evaluation of the ux"] OR [Abstract: "evaluate the ux"] OR [Abstract: "measuring the ux"] OR [Abstract: "measurement of the ux"] OR [Abstract: "measure the ux"] OR [Abstract: "tool of the ux"] OR [Abstract: "evaluating the user experience"] OR [Abstract: "evaluation of the user experience"] OR [Abstract: "evaluate the user experience"] OR [Abstract: "measuring the user experience"] OR [Abstract: "measurement of the user experience"] OR [Abstract: "measure the user experience"] OR [Abstract: "tool of the user experience"] OR [Abstract: "dimension of the user experience"] OR [Abstract: "aspect of the user experience"] OR [Abstract: "attribute of the user experience"] OR [Abstract: "indicator of the user experience"] OR [Abstract: "component of the user experience"] OR [Abstract: "factor of the user experience"] OR [Abstract: "element of the user experience"] OR [Abstract: "dimensions of the user experience"] OR [Abstract: "aspects of the user experience"] OR [Abstract: "attributes of the user experience"] OR [Abstract: "indicators of the user experience"] OR [Abstract: "components of the user experience"] OR [Abstract: "factors of the user experience"] OR [Abstract: "elements of the user experience"] OR [Abstract: "dimension of user experience"] OR [Abstract: " aspect of user experience"] OR [Abstract: " attribute of user experience"] OR [Abstract: "indicator of user experience"] OR [Abstract: " component of user experience"] OR [Abstract: "factor of user experience"] OR [Abstract: " element of user experience"] OR [Abstract: "dimensions of user experience"] OR [Abstract: " aspects of user experience"] OR [Abstract: " attributes of user experience"] OR [Abstract: "indicators of user experience"] OR [Abstract: " components of user experience"] OR [Abstract: "factors of user experience"] OR [Abstract: " elements of user experience"]

APPENDIX 2

UX dimensions covered in different UX evaluation tools

Table 21- UX tools and the dimensions they cover

No	UX tools	Usability	Utility	Emotion	Hedonic	Engagement	Social	Informational	Sensory	Impact on body	Judgment	Physical	Cognitive	Overall UX	Others	Total
1	MEEGA+	✓	-	-	✓	✓	✓	✓	✓	-	✓	-	✓	✓	✓	10
2	Laine (2016)	✓	-	✓	✓	✓	-	✓	✓	-	✓	✓	-	✓	-	9
3	UX in IVE	✓	✓	✓	✓	✓	-	-	✓	✓	✓	-	-	-	✓	9
4	Jang (2019)	✓	✓	-	✓	-	✓	✓	✓	-	-	✓	-	-	✓	8
5	Moizer (2019)	✓	-	✓	✓	✓	-	-	✓	-	-	-	✓	✓	✓	8
6	Abro (2019)	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	-	-	-	7
7	GEQ	-	-	✓	-	✓	✓	-	✓	✓	-	-	-	✓	✓	7
8	GUESS	✓	-	-	✓	✓	✓	-	✓	-	✓	-	-	-	✓	7
9	Krawczyk (2017)	✓	✓	-	✓	-	✓	-	✓	-	-	-	✓	✓	-	7
10	meCUE	✓	✓	✓	✓	-	-	-	✓	-	✓	-	-	✓	-	7
11	Nielsen (2018)	✓	✓	✓	✓	-	-	-	✓	-	-	✓	-	-	✓	7
12	Park (2018)	✓	✓	-	✓	-	✓	✓	✓	-	-	✓	-	-	-	7
13	Park (2013)	✓	✓	-	✓	-	✓	✓	✓	-	-	✓	-	-	-	7
14	Buchner (2012)	✓	✓	✓	-	-	-	-	-	✓	-	-	-	✓	✓	6
15	EDUGXQ	✓	✓	-	✓	✓	-	-	-	-	-	-	✓	-	✓	6
16	EGameFlow	✓	-	-	-	✓	✓	-	-	✓	-	-	✓	-	✓	6
17	Orehovacki (2018)	✓	✓	-	✓	-	✓	-	✓	✓	-	-	-	-	-	6
18	Pretto (2020)	✓	-	-	✓	-	-	✓	✓	-	-	-	✓	-	✓	6
19	Roth (2016)	✓	-	✓	✓	✓	-	-	✓	-	-	-	-	-	✓	6
20	SASSI	✓	✓	✓	✓	-	-	-	-	✓	✓	-	-	-	-	6
21	UEQ+	✓	✓	-	✓	-	-	✓	✓	-	-	-	-	✓	-	6
22	VRLEQ	✓	-	✓	-	✓	-	-	-	✓	✓	-	-	-	✓	6
23	Zhuo (2013)	✓	✓	✓	✓	-	✓	-	-	-	✓	-	-	-	-	6
24	Aestimo	✓	✓	-	✓	-	-	-	✓	-	-	-	-	✓	-	5
25	AttrakDiff	✓	✓	-	✓	-	-	-	✓	-	-	-	-	✓	-	5
26	CEGEQ	✓	-	-	✓	-	-	-	✓	-	✓	-	-	-	✓	5
27	CSUQ	✓	✓	-	✓	-	-	✓	-	-	-	-	-	✓	-	5
28	Cuadros (2021)	✓	✓	-	✓	✓	-	-	-	-	-	-	✓	-	-	5
29	FASER LX	✓	✓	-	✓	-	✓	✓	-	-	-	-	-	-	-	5
30	Lachner (2016)	✓	✓	-	✓	-	-	✓	✓	-	-	-	-	-	-	5
31	Macedo (14)	✓	✓	-	✓	-	-	-	✓	-	-	✓	-	-	-	5
32	Ormeno (2019)	✓	-	✓	✓	✓	-	-	-	-	✓	-	-	-	-	5
33	PSSUQ	✓	✓	-	✓	-	-	✓	-	-	-	-	-	✓	-	5
34	QUIS	✓	-	-	✓	-	-	✓	✓	-	-	-	-	✓	-	5

No	UX tools	Usability	Utility	Emotion	Hedonic	Engagement	Social	Informational	Sensory	Impact on body	Judgment	Physical	Cognitive	Overall UX	Others	Total
35	Saun (2021)	-	✓	-	-	-	-	-	-	✓	✓	✓	-	✓	-	5
36	UEQ	✓	✓	-	✓	-	-	-	✓	-	-	-	-	✓	-	5
37	UES	✓	-	-	✓	✓	-	-	✓	-	-	✓	-	-	-	5
38	UXQ4RL	✓	✓	-	✓	✓	-	-	-	-	-	-	✓	-	-	5
39	Van de laar (2010)	✓	-	-	-	✓	-	-	-	✓	-	-	-	✓	✓	5
40	VRNQ	-	-	-	✓	✓	-	-	✓	✓	-	-	-	-	✓	5
41	Chinese UX quest.	✓	✓	-	✓	-	✓	-	-	-	-	-	-	-	-	4
42	EVEQ-GP	✓	-	✓	✓	✓	-	-	-	-	-	-	-	-	-	4
43	Flow4D16	✓	-	-	✓	✓	-	-	-	✓	-	-	-	-	-	4
44	FSS	✓	-	-	✓	✓	-	-	-	-	-	-	-	-	✓	4
45	IMI	-	✓	-	✓	-	-	-	-	✓	-	-	-	-	✓	4
46	IVRUX	✓	-	-	-	✓	-	-	-	✓	✓	-	-	-	-	4
47	MAX	✓	✓	✓	-	-	-	-	-	-	✓	-	-	-	-	4
48	MUX	✓	-	-	-	-	✓	✓	-	-	-	✓	-	-	-	4
49	PENS	✓	-	-	✓	✓	-	-	-	-	-	-	-	-	✓	4
50	PQ	✓	-	-	-	✓	-	-	✓	-	-	-	-	-	✓	4
51	Reaction cards	✓	✓	-	✓	-	-	-	-	-	-	-	-	✓	-	4
52	SGUS	✓	✓	-	-	✓	-	✓	-	-	-	-	-	-	-	4
53	Short UEQ	✓	✓	-	✓	-	-	-	-	-	-	-	-	✓	-	4
54	SUXES	✓	✓	-	✓	-	-	-		-	✓	-	-	-	-	4
55	UES-SF	✓	-	-	✓	✓	-	-	✓	-	-	-	-	-	-	4
56	USE	✓	✓	-	✓	-	-	-	-	-	✓	-	-	-	-	4
57	UX Curve	✓	✓	-	✓	-	-	-	-	-	-	-	-	✓	-	4
58	UXS	✓	✓	-	✓	-	-	-	-	-	-	-	-	✓	-	4
59	VOF	✓	-	-	-	-	-	✓	-	✓	-	✓	-	-	-	4
60	CAS	✓	-	-	✓	✓	-	-	-	-	-	-	-	-	-	3
61	Fun toolkit	✓	-	-	✓	-	-	-	-	-	✓	-	-	-	-	3
62	GodSpeed questionnaire	-	-	✓	✓	-	-	-	-	-	-	-	-	-	✓	3
63	HED/UT	✓	✓	-	✓	-	-	-	-	-	-	-	-	-	-	3
64	Honeycomb	✓	✓	-	✓	-	-	-	-	-	-	-	-	-	-	3
65	iScale	✓	✓	-	✓	-	-	-	-	-	-	-	-	-	-	3
66	ITC-SOPI	-	-	-	-	✓	-	-	-	✓	-	-	-	-	✓	3
67	ITVUX	-	-	✓	✓	-	-	-	✓	-	-	-	-	-	-	3
68	SUISQ-R	✓	-	-	-	-	-	-	-	-	✓	-	-	-	✓	1
69	UEQ-S	✓	✓	-	✓	-	-	-	-	-	-	-	-	-	-	3
70	UXSC	✓	✓	-	✓	-	-	-	-	-	-	-	-	-	-	3
71	Yang (2018)	✓	-	-	-	-	-	✓	✓	-	-	-	-	-	-	3
72	Yu (2019)	✓	-	-	-	-	-	-	-	✓	-	✓	-	-	-	3
73	3E, 3E*	-	-	✓	-	-	-	-	-	-	-	-	-	✓	-	2

No	UX tools	Usability	Utility	Emotion	Hedonic	Engagement	Social	Informational	Sensory	Impact on body	Judgment	Physical	Cognitive	Overall UX	Others	Total
74	INTUI	✓	-	-	✓	-	-	-	-	-	-	-	-	-	-	2
75	PGQ	-	-	-	-	-	-	-	-	✓	-	-	-	✓	-	2
76	SUS (System Usability Scale)	✓	-	-	-	-	-	-	-	-	✓	-	-	-	-	2
77	DALI	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	1
78	Comfort/Discomfort	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	1
79	Emoti-SAM	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	1
80	FKS	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	1
81	FMS	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	1
82	Geneva emo. wheel	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	1
83	GEQ (Engagement)	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	1
84	HabuT instrument	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	1
85	I-PANAS-SF	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	1
86	Klein (2020)	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	1
87	Korber (2013)	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	1
88	MSAQ	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	1
89	NASA-TLX	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	1
90	NPS	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	1
91	PANAS	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	1
92	PPA	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	1
93	PrEmo	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	1
94	SAM	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	1
95	SEA	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	1
96	SEI	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	1
97	SEQ	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	1
98	SMEQ	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	1
99	SSQ	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	1
100	SUS (Slater-Usoh-Steed)	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	1
101	TACTUX	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	1
102	UNeeQ	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	1
103	UX needs scale	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	1
104	VisAWI	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	1