Construction of the UXAR-CT – a User eXperience Questionnaire for Augmented Reality in Corporate Training

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RESUME

Measuring User Experience (UX) with questionnaires is essential for developing and improving products. However, no domain-specific standardized UX questionnaire exists for Augmented Reality (AR) in Corporate Training (CT). Thus, this study introduces the UXAR-CT questionnaire - an AR-specific UX questionnaire for CT environments.
We describe the construction procedure and the evaluation process of the questionnaire. A set of candidate items was constructed, and a larger sample of participants evaluated several AR-based learning scenarios with these items.
Based on the results, we performed a Principal Component Analysis (PCA) to identify relevant measurement items for each scale. The three best-fitting items were selected based on the results to form the final questionnaire. The first results regarding scale quality indicate a high level of internal consistency. The final version of the UXAR-CT questionnaire is provided and will be evaluated in further research.

Keywords– *UXAR-CT; User Experience (UX); UX Measurement; UX Quality Aspects; Questionnaire Construction and Evaluation; Augmented Reality (AR); Corporate Training (CT).*

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AGENDA

1. Introduction & Related Research
2. Methodology
3. Results
4. Conclusion

AUGMENTED REALITY

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> *Augmented Reality (AR) allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore,* ***AR supplements reality****, rather than completely replacing.* *(Azuma 1997)*

- AR is supported on current mobile devices due to rapid development and technical pogress *(Irshad & Rambli 2017, Dirin & Laine 2018)*
- High potential for improving training and education *(Billinghurst & Dünser 2012, Dirin & Laine 2018, Chang et al. 2020, Criollo-C et al. 2021)*

// differentiation between academic teaching and ***corporate training*** (CT)

// **only little research** in the field of corporate training

// capturing and experiencing content in a new way

// **multimodality** and **interactivity** in learning

AR enhances both teaching and learning activities *(Billinghurst & Dünser 2012, Chang et al. 2020, Criollo-C et al. 2021)*

USER EXPERIENCE

> *person's perceptions and responses that result from the use or anticipated use of a product, system or service (DIN ISO 9241-210)*

- UX is an **success factor** in the development and improvement of information systems *(Rauschenberger et al. 2013, Boland 2021)*

➔ **Goal: creating a positive user experience** *(Boland 2021)*

- Multidimensional construct evaluating the overall impression (Santoso & Schrepp 2019)
- Different dimensions/quality aspects (Schrepp et al. 2023)
- UX quality aspects describe the subjective impression of users towards a "**semantically clearly described aspect"** of product usage or product design (Schrepp et al. 2023)

UX quality aspects

(1) Efficiency [EF]
(2) Perspicuity [PE]
(3) Dependability [DE]
(4) Usefulness [US]
(5) Intuitive Use [IU]
(6) Adaptability [AD]
(7) Novelty [NO]
(8) Stimulation [ST]
(9) Clarity [CL]
(10) Quality of Content [QC]
(11) Immersion [IM]
(12) Aesthetics [AE]
(13) Value [VA]
(14) Identity [ID]
(15) Loyalty [LO]
(16) Trust [TR]

MEASURING USER EXPERIENCE

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- **Need** to **understand** and **measure** the **UX** and its **dimensions** to improve products, systems and services *(Irshad et al. 2020, Preece et al., 2015)*

- **Various empirical methods** can be found in literature for measuring the UX

  (Preece et al. 2015, Assila et al. 2016, Albert & Tullis 2022)

  // **Self-reported metrics** (subjective methods) most suitable to gather direct user feedback

  // questionnaires are quickly, simply and cost-effectively

Measuring UX by questionnaires as most established method *(Schrepp 2020, Albert & Tullis 2022)*

USER EXPERIENCE QUESTIONNAIRES

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- Many standardized UX questionnaires *(Schrepp 2020)*
- Questionnaires are based on **different dimensions (UX quality aspects), items, and scales** in relation to their specific focus of UX *(Hinderks et al. 2019, Schrepp 2020, Schrepp et al. 2023)*

  // New products create new interaction paradigms → existing questionnaires differ in the **UX quality aspects, items, and scales**

  // **Not** all UX quality aspects are **equally important** for all products

→ **The questionnaires' structure and focus refers to the respective research and evaluation objective** *(Schrepp 2020, Albert & Tullis 2022)*

→ **Need to determine the importance of UX quality aspects concerning the evaluation object** *(Schrepp 2020, Schrepp 2023)*

RELATED RESEARCH

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- Only a limited number of UX questionnaires for immersive technology *(Graser 2024)*
- Only **three** UX questionnaires for AR *(Graser 2024)*

	HARUS Handheld Augmented Reality Usability Scale	**ARI** Augmented Reality Immersion Questionnaire	**CIQ** Customizable Interaction Questionnaire
name			
focus	***Usability*** of handheld AR devices	***Immersion*** in location-aware AR settings	***Quality of Interaction*** with objects
factors	*Comprehensibility* *Manipulability*	*Engagement* *Engrossment* *Total Immersion*	*Quality of Interactions* *Comfort* *Assessment of Task Performance* *Consistency with Expectation* *Quality of the Sensory Enhancements*
Item format	16 items	21 items	17 items
scale format	7-point rating scale	7-point rating scale	5-point rating scale
source	*Santos et al. 2014; Santos et al. 2015*	*Georgiou & Kyza 2017*	*Gao & Boehm-Davis 2022*

RESEARCH OBJECTIVE

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- No common understanding of the importance of specific UX quality aspects for (M)AR
- No established method for measuring the UX of (M)AR
- No established standardized UX questionnaire for (M)AR
- Existing UX questionnaires for AR **differ** in **structure** and **focus**

Construction of an AR-specific standardized UX questionnaire for CT

User e**X**perience **A**ugmented **R**eality **– C**orporate **T**raining Questionnaire | **UXAR-CT**

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DEVELOPMENT OF THE UXAR-CT

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(1) Consideration of the most important UX Quality Aspects
Five most important UX quality aspects

↓

(2) Generation of an Item Pool
Selection of 5 suitable items based on 60 UX questionnaires and 1500 items

↓

(3) Survey Design
25 statements concerning the UX quality aspects and one overall user satisfaction items based on a 7-point Likert scale *(don't agree at all … fully agree)*

↓

(4) Data Collection
AR-based learning applications in CT scenarios at the Chamber of Crafts (n = 103)

↓

(5) Questionnaire Evaluation and Item Selection
Principal Component Analysis (PCA) and reduction of the item pool based on the item correlations

AUGMENTED REALITY CORPORATE TRAINING SCENARIO

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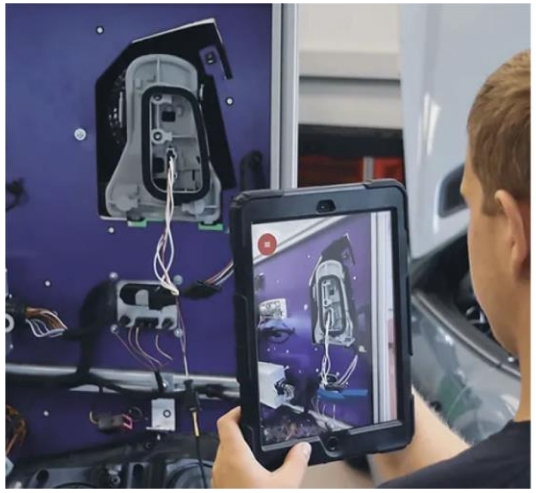
- Collaboration with the Chamber of Crafts for Lower Franconica in Schweinfurt, Bavaria, Germany → **regular use of five AR-based learning scenarios**

(1) Troubleshooting and use of measurement devices on a car lighting wall
(2) Processing of high-grade steel and aluminum
(3) Installation of locking and security systems
(4) Changing the timing belt on a car engine
(5) Testing of electronic devices

- Scenarios are integrated in courses
- Head-mounted and handheld devices
- Step-to-step learning instructions



Source: https://www.projekt-ariha.de/projekt-ariha

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RESULTS – PRINCIPAL COMPONENT ANALYSIS

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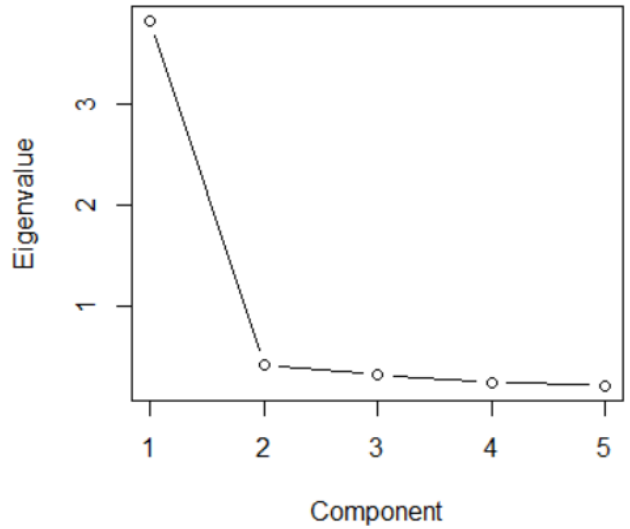
→ **Analysis (n = 103)** of **uni-dimensionality** of the candidate items based on a **PCA** with **varimax rotation (scree-test** and **Kaiser-Gutmann criterion)**

UX Quality Aspect: **Efficiency**
Subjective impression of users who can complete the task with mobile augmented reality without unnecessary effort.

#	Measurement Item
EF1	Using the application for learning is practical
EF2	The application reduces the learning effort
EF3	The application helps me to learn faster
EF4	The application saves me time while learning
EF5	The application improves my learning and work performance

Scree plot of the eigenvalues from the PCA



→ Analysis indicates **semantic homogeneity** of the candidate items **for all proposed scales**

RESULTS (2) – ITEM SELECTION

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→ **Selection** of best-fitting items based on the **loadings** of the **correlation** between *candidate items* and *overall satisfaction (correlation > 0.40)*

#	Measurement Item	Correlation
EF1	Using the application for learning is practical	**0.72**
EF2	The application reduces the learning effort	0.41
EF3	The application helps me to learn faster	**0.62**
EF4	The application saves me time while learning	0.47
EF5	The application improves my learning and work performance	**0.62**

Correlation between the items of the UX quality aspects and the overall satisfaction

RESULTS (2) – REDUCED UXAR-CT

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UX Quality Aspect	Translated Measurement Item	Cor.	Cronbach's Alpha
Overall Satisfaction	Overall, I am satisfied with the support provided by the application for my learning tasks		
Efficiency: **EF1**	Using the application for learning is practical	**0.72**	
Efficiency: **EF3**	The application helps me to learn faster	**0.62**	**0.90**
Efficiency: **EF5**	The application improves my learning and work performance	**0.62**	
Perspicuity: **PE2**	It is easy/simple to learn how to use the application	**0.63**	
Perspicuity: **PE3**	The information in the application is easy to understand	**0.63**	**0.81**
Perspicuity: **PE4**	The operation of the application is logical	**0.55**	
Dependability: **DE3**	The application is easy to control	**0.63**	
Dependability: **DE4**	I always have control over the application at every step	**0.55**	**0.85**
Dependability: **DE5**	It is easy to find your way around the application	**0.51**	
Usefulness: **US1**	The application helps me to learn	**0.67**	
Usefulness: **US2**	It is a great advantage to use the application when learning	**0.67**	**0.95**
Usefulness: **US4**	find the application useful for learning	**0.68**	
Clarity: **CL1**	The information on the display is clearly laid out	**0.54**	
Clarity: **CL2**	The information on the display is clear	**0.48**	**0.79**
Clarity: **CL4**	It's easy to find the information I need	**0.55**	

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CONCLUSION

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Discussion		Future Research
AR in CT not very widespread → difficulty of data collection	→	Cooperation with the Chamber of Handicrafts → Regular use of AR
Questionnaire focuses purely on the UX perspective	→	Validation and extension of the questionnaire concerning relevant system properties

CONCLUSION

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- **Identification of relevant UX quality aspects for AR in CT**
- **First proposed AR-specific standardized UX questionnaire for CT**

  // structure based on a common foundation regarding the UX perspective

  // evaluation based on regular AR-based learning scenarios in CT
- **Contribution to the existing lack of research in this field**

THANK YOU FOR YOUR ATTENTION!

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Connect!

REFERENCES (1/3)

Albert, W.B., Tullis, T.T.: Measuring the User Experience. Collecting, Analyzing, and Presenting UX Metrics. Morgan Kaufmann (2022)

Assila, A., de Oliveira, K.M., Ezzedine, H.: Standardized usability questionnaires features and quality focus. Comput. Sci. Inf. Technol. 6 (2016). https://api.semanticscholar.org/CorpusID:54726201

Azuma, R.T.: A survey of augmented reality. Presence Teleoperators Virtual Environ. 6, 355–385 (1997)

Billinghurst, M., Duenser, A.: Augmented reality in the classroom. Computer 45(7), 56–63 (2012). https://doi.org/10.1109/MC.2012.111

Brooke, J.: SUS: a quick and dirty usability scale. Usability Eval. Ind. 189(194), 4–7 (1995)

Chang, Y.S., Hu, K.J., Chiang, C.W., Lugmayr, A.: Applying mobile augmented reality (AR) to teach interior design students in layout plans: evaluation of learning effectiveness based on the arcs model of learning motivation theory. Sensors 20(1), 105 (2020) https://doi.org/10.3390/s20010105, https://www.mdpi.com/1424-8220/20/1/105

Chin, J.P., Diehl, V.A., Norman, K.L.: Development of an instrument measuring user satisfaction of the human-computer interface. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 213–218 (1988)

Criollo-C, S., Abad-Vasquez, D., Martic-Nieto, M., Velasquez-G, F.A., Perez-Medina, J.L., Lujan-Mora, S.: Towards a new learning experience through a mobile application with augmented reality in engineering education. Appl. Sci. 11(11), 4921 (2021). https://www.mdpi.com/2076-3417/11/11/4921

Dirin, A., Laine, T.: User experience in mobile augmented reality: emotions, challenges, opportunities and best practices. Computers 7, 33 (2018). https://doi.org/10.3390/computers7020033

Diaz-Oreiro, I., Lopez, G., Quesada, L., Guerrero, L.A.: Standardized questionnaires for user experience evaluation: a systematic literature review. Proceedings 31, 14 (2019).https://doi.org/10.3390/proceedings2019031014

Gao, M., Boehm-Davis, D.: Development of a customizable interactions questionnaire (CIQ) for evaluating interactions with objects in augmented/virtual reality. Virtual Reality 27, 1–18 (2022).https://doi.org/10.1007/s10055-022-00678-8

Georgiou, Y., Kyza, E.A.: The development and validation of the ARI questionnaire: an instrument for measuring immersion in location-based augmented reality settings. Int. J. Hum Comput. Stud. 98, 24–37 (2017). https://doi.org/10.1016/j.ijhcs.2016.09.014

Graser, S., Bohm, S.: Quantifying user experience through self-reporting questionnaires: a systematic analysis of the sentence similarity between the items of the measurement approaches. In: Stephanidis, C., Antona, M., Ntoa, S., Salvendy, G. (eds.) HCI International 2023 - Late Breaking Posters, pp. 138–145. Springer Nature Switzerland, Cham (2024). https://doi.org/10.1007/978-3-031-49212-9_19

Graser, S., Bohm, S.: A systematic literature review on technology acceptance research on augmented reality in the field of training and education. In: CENTRIC 2022, The Fifteenth International Conference on Advances in Human-oriented and Personalized Mechanisms, Technologies, and Services, pp. 20–22 (2022).

Graser, S., Bohm, S.: Applying augmented SBERT and BERTopic in UX research: a sentence similarity and topic modeling approach to analyzing items from multiple questionnaires. In: Proceedings of the IWEMB 2023, Seventh International Workshop on Entrepreneurship, Electronic, and Mobile Business (2023)

REFERENCES (2/3)

Graser, S., Böhm, S., Schrepp, M.: Using chatGPT-4 for the identification of common UX factors within a pool of measurement items from established UX questionnaires. In: CENTRIC 2023, The Sixteenth International Conference on Advances in Human-oriented and Personalized Mechanisms, Technologies, and Services (2023)

Graser, S., Schrepp, M., Böhm, S.: “UXAR-CT – an approach for measuring UX for mobile augmented reality applications in corporate training,” in Human-Centered Design, Operation and Evaluation of Mobile Communications, J.Wei and G. Margetis, Eds., Cham: Springer Nature Switzerland, 2024, pp. 211–234, isbn: 978-3-031-60458-4.

Hassenzahl, M.: The Thing and I: Understanding the Relationship Between User and Product, pp. 31–42. Springer Netherlands, Dordrecht (2004).https://doi.org/10.1007/1-4020-2967-5_4

Hinderks, A., Winter, D., Schrepp, M., Thomaschewski, J.: Applicability of user experience and usability questionnaires. J. Univers. Comput. Sci. 25, 1717–1735 (2019). https://api.semanticscholar.org/CorpusID:210937088

Irshad, S., Rambli, D.R.A.: Advances in mobile augmented reality from user experience perspective: a review of studies. In: International Visual Informatics Conference (2017)

Karapanos, E., Zimmerman, J., Forlizzi, J., Martens, J.B.: User experience over time: an initial framework. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 729–738 (2009)

Kirakowski, J., Corbett, M., Sumi, M.: The software usability measurement inventory. Br. J. Educ. Technol. 24(3), 210–2 (1993)

Kuroso, M., Kashimura, K.: Apparent usability vs. inherent usability, chi’95 conference companion. In: Conference on Human Factors in Computing Systems, Denver, Colorado, pp. 292–293 (1995)

Laugwitz, B., Held, T., Schrepp, M.: Construction and evaluation of a user experience questionnaire. In: Holzinger, A. (ed.) HCI and Usability for Education and Work, pp. 63–76. Springer, Berlin Heidelberg, Berlin, Heidelberg (2008)

Lin, H.X., Choong, Y.Y., Salvendy, G.: A proposed index of usability: a method for comparing the relative usability of different software systems. Behav. Inf. Technol. 16(4–5), 267–277 (1997)

Raita, E., Oulasvirta, A.: Too good to be bad: favorable product expectations boost subjective usability ratings. Interact. Comput. 23(4), 363–371 (2011)

Rauschenberger, M., Schrepp, M., Cota, M.P., Olschner, S., Thomaschewski, J.: Efficient measurement of the user experience of interactive products. How to use the user experience questionnaire (UEQ).example: Spanish language version. Int. J. Interact. Multim. Artif. Intell. 2, 39–45 (2013)

Rogers, Y., Sharp, H., Preece, J.: Interaction Design-Beyond Human-Computer Interaction Wiley, 2002. Google Scholar Google Scholar Digital Library Digital Library (2002)

Rohrer, C.: When to use which user-experience research methods (2022). https://www.nngroup.com/articles/which-ux-research-methods/. retrieved: 10/2023

Santos, M.E.C., Polvi, J., Taketomi, T., Yamamoto, G., Sandor, C., Kato, H.: Toward standard usability questionnaires for handheld augmented reality. IEEE Comput. Graphics Appl. 35(5), 66–75 (2015). https://doi.org/10.1109/MCG.2015.94

Santos, M.E.C., Taketomi, T., Sandor, C., Polvi, J., Yamamoto, G., Kato, H.: A usability scale for handheld augmented reality. In: VRST ’14, Association for Computing Machinery, New York, NY, USA (2014). https://doi.org/10.1145/2671015.2671019

Santoso, H.B., Schrepp, M.: The impact of culture and product on the subjective importance of user experience aspects. Heliyon 5, e02434 (2019). https://api.semanticscholar.org/CorpusID:202579259

REFERENCES (3/3)

Schrepp, M.: UEQ+ a modular extension of the user experience questionnaire (2019). http://www.ueqplus.ueq-research.org/. retrieved: 10/2023

Schrepp, M.: A comparison of UX questionnaires - what is their underlying concept of user experience? In: Hansen, C., Nurnberger, A., Preim, B. (eds.) Mensch und Computer 2020 - Workshopband. Gesellschaft fur Informatik e.V., Bonn (2020). https://doi.org/10.18420/muc2020-ws105-236

Schrepp, M.: User Experience Questionnaires: How to use questionnaires to measure the user experience of your products? KDP, ISBN-13: 979-8736459766 (2021)

Schrepp, M., et al.: On the importance of UX quality aspects for different product categories. Int. J. Interact. Multimedia Artif. Intell. 8, 1 (2023). https://doi.org/10.9781/ijimai.2023.03.001

Schrepp, M., Thomaschewski, J.: Design and validation of a framework for the creation of user experience questionnaires. Int. J. Interact. Multimedia Artif. Intell. InPress, 1 (2019). https://doi.org/10.9781/ijimai.2019.06.006

Somrak, A., Pogačnik, M., Guna, J.: Suitability and comparison of questionnaires assessing virtual reality-induced symptoms and effects and user experience in virtual environments. Sensors 21(4), 1185 (2021).https://doi.org/10.3390/s21041185

International Organisation for Standardization 9241-210:2019: Ergonomics of human-system interaction Part 210: Human-centred design for interactive systems. ISO - International Organization for Standardization (2019)

Subandi, Joniriadi, Syahidi, A.A., Mohamed, A.: Mobile augmented reality application with multi-interaction for learning solutions on the topic of computer network devices (effectiveness, interface, and experience design). In: 2020 Third International Conference on Vocational Education and Electrical Engineering (ICVEE), pp. 1–6 (2020).https://doi.org/10.1109/ICVEE50212.2020.9243292

Tcha-Tokey, K., Loup-Escande, E., Christmann, O., Richir, S.: A questionnaire to measure the user experience in immersive virtual environments (2016). https://doi.org/10.1145/2927929.2927955

Thuring, M., Mahlke, S.: Usability, aesthetics and emotions in human-technology interaction. Int. J. Psychol. 42(4), 253–264 (2007)

Tractinsky, N.: Aesthetics and apparent usability: empirically assessing cultural and methodological issues. In: Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems, pp. 115–122 (1997)

UEQ, T.: UEQ user experience questionnaire (2018). https://www.ueq-online.org/. retrieved: 10/2023

Willumeit, H., Gediga, G., Hamborg, K.C.: Isometricsl: Ein verfahren zur formativen evaluation von software nach iso 9241/10. Ergonomie und Informatik 27, 5–12 (1996)

Winter, D., Hinderks, A., Schrepp, M., Thomaschewski, J.: Welche ux faktoren sind fur mein produkt wichtig? Mensch und Computer 2017-Usability Professionals (2017)

Winter, D., Schrepp, M., Thomaschewski, J.: Faktoren der User Experience: Systematische Ubersicht uber produktrelevante UX-Qualitatsaspekte, pp. 33–41. De Gruyter, Berlin, Munchen, Boston (2015).https://doi.org/10.1515/9783110443882-005