User Experience of Augmented Reality: A Systematic Literature Review

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30th September 2024, Venice, Italy – paper presentation 30013

RESUMÉ

Due to technological development, Augmented Reality (AR) can be applied in different domains. However, innovative technologies refer to new interaction paradigms, thus creating a new experience for the user. This so-called User Experience (UX) is essential for developing and designing interactive products. Moreover, UX must be measured to get insights into the user's perception and, thus, to improve innovative technologies. We conducted a Systematic Literature Review (SLR) to provide an overview of the current research concerning UX evaluation of AR. In particular, we aim to identify (1) research referring to UX evaluation of AR and (2) articles containing AR-specific UX models or frameworks concerning the theoretical foundation. The SLR is a five-step approach including five scopes. From a total of 498 records based on eight search terms referring to two databases, 30 relevant articles were identified and further analyzed. Results show that most approaches concerning UX evaluation of AR are quantitative. In summary, five UX models/frameworks were identified. Concerning the UX evaluation results of AR in Training and Education, the UX was consistently positive. Negative aspects refer to errors and deficiencies concerning the AR system and its functionality. No specific metric for UX evaluation of AR in the field of Training and Education exists. Only three AR-specific standardized UX questionnaires could be found. However, the questionnaires do not refer to the field of Training and Education. Thus, there is a lack of research in the field of UX evaluation of AR in Training and Education.

Keywords–User Experience (UX); UX Evaluation; (Mobile) Augmented Reality (M)AR; Systematic Literature Review (SLR)

AGENDA

1. Introduction
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)*

- Widespread in different application fields due to technical progress *(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)*

  // capturing and experiencing content in a new way

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

→ AR can enhance both teaching and learning activities *(Billinghurst & Dünser 2012; Chang et al. 2020; Criollo-C et al. 2021)*

New technologies enable new interaction paradigms and, thus, a new experience for users

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)*

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- **Multidimensional** construct describing the overall impression (Santoso & Schrepp 2019)
- UX is an **success factor** in the development and improvement of information systems *(Rauschenberger et al. 2013; Boland 2021)*
- **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 *(Assila et al. 2016; Rohrer 2022; Albert & Tullis 2022)*

→ **Goal: creating a positive user experience** *(Schrepp 2020)*

RESEARCH OBJECTIVE & QUESTIONS

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Providing the current state of research concerning UX of AR

- Focus on UX evaluation
- Special interest in the field of training and education

RQ1: Which methods were applied for measuring UX in the context of AR?

RQ2: What theoretical models and frameworks exist concerning UX and AR?

RQ3: What results were conducted in UX research regarding AR in the domain of training and education?

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SYSTEMATIC LITERATURE REVIEW (SLR)

Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (Moher et al. 2009)

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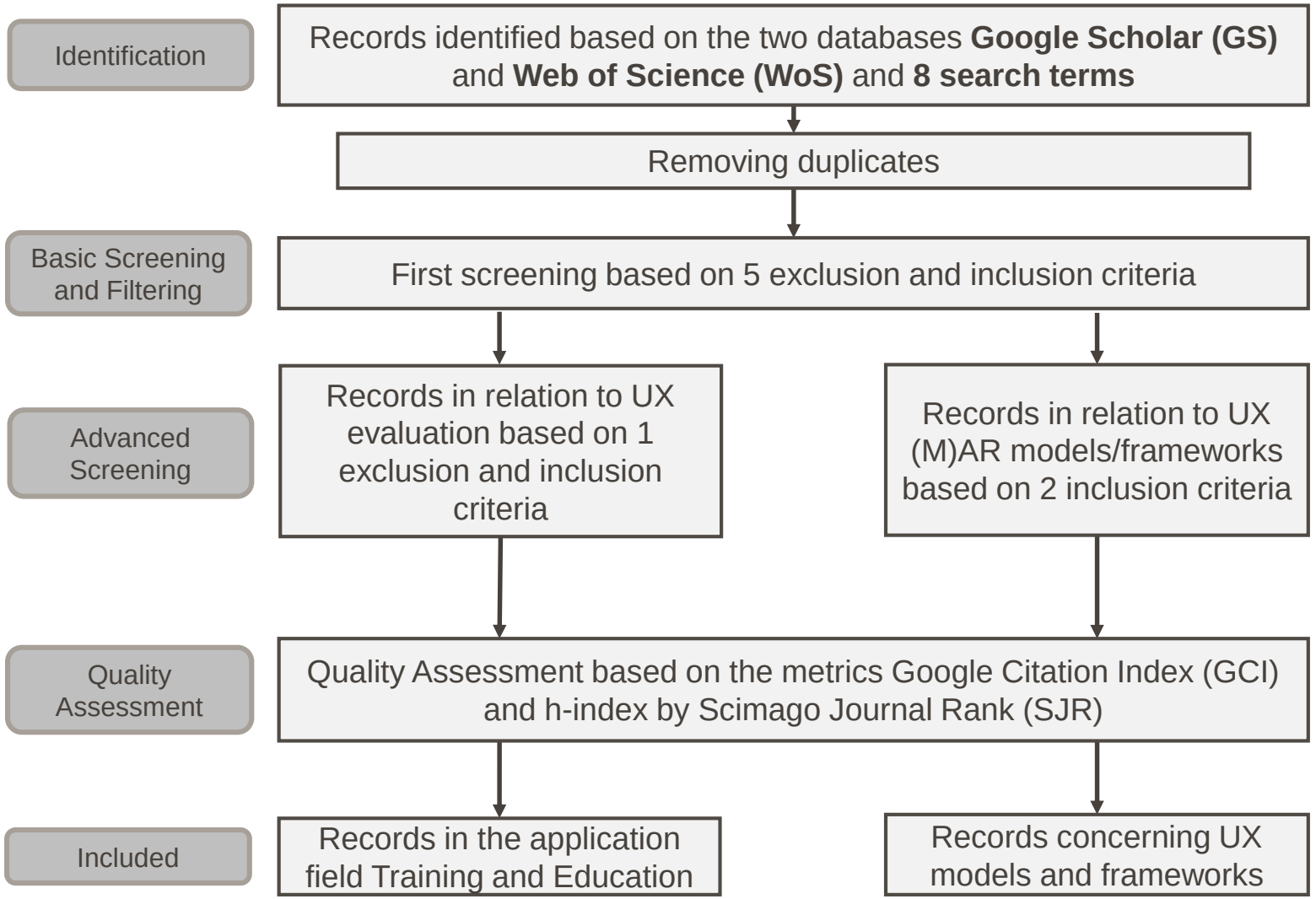


SCOPES

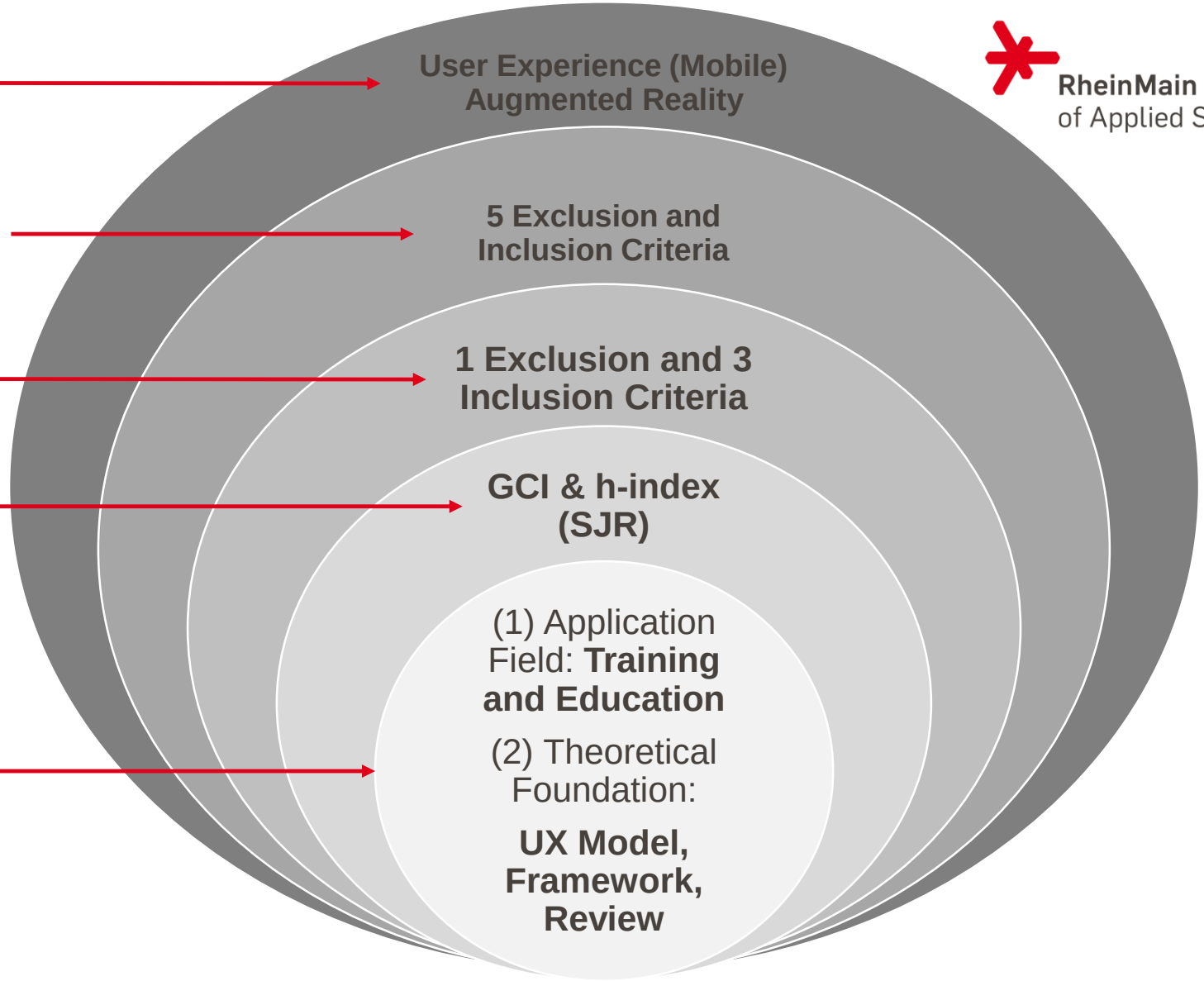
(1) Record Idendification

(2) Basic Screening & Filtering

(3) Advanced Screening

(4) Quality Assessment

(5) Included



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(1) INDENTIFICATION

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Databases:

- Web of Science (WoS)
- Google Scholar (GS)

Search terms:

- ”User Experience Augmented Reality”
- ”User Experience Mobile Augmented Reality”
- ”UX Augmented Reality”
- ”UX Mobile Augmented Reality”
- ”UX AR”
- ”UX MAR”
- ”User Experience AR”
- ”User Experience MAR”

(2) BASIC SCREENING & (3) ADVANCED SCREENING

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Inclusion criteria	Exclusion criteria
Basic Screening	
(in1) Focus on UX of AR	(ex1) Focus on VR instead of AR
(in2) Accessibility of full-text	(ex2) No accessibility of full-text
(in3) Research language English	(ex3) Written in non-English
(in4) Peer-reviewed	(ex4) Grey literature
(in5) Empirical data collection or theoretical model/framework (also SLR)	(ex5) insufficient information
Advanced Screening	
(in6) UX/Usability evaluation goal	(ex6) Lack of focus in UX/Usability evaluation goal
(in7) UX model/framework included	
(in8) Systematic Literature Review	

(4) QUALITY ASSESSEMENT

- Classification of all papers into their type
  B = Book chapter
  J = Journal article
  C = Conference proceedings

- Application of two measures:

(1) **Google Citation Index** (GCI)
→ Calculation of the Average Citation Count (ACC)
= *Overall citations count divided by the number of years*

(2) **h-index** by Scimago Journal Rankings

- Using the **median** as threshold for both measures*

Median	Book chapter	Journal article	Conference proceedings
GCI	***1.62***	***2.5***	***1.5***
h-index	***0***	***46***	***7***

**large discrepancy* *in the metrics values for model/framework papers*
→ *quality assessment for the eleven articles was **rather difficult***

→ *articles with at least **five overall citations** included*

APPROACH

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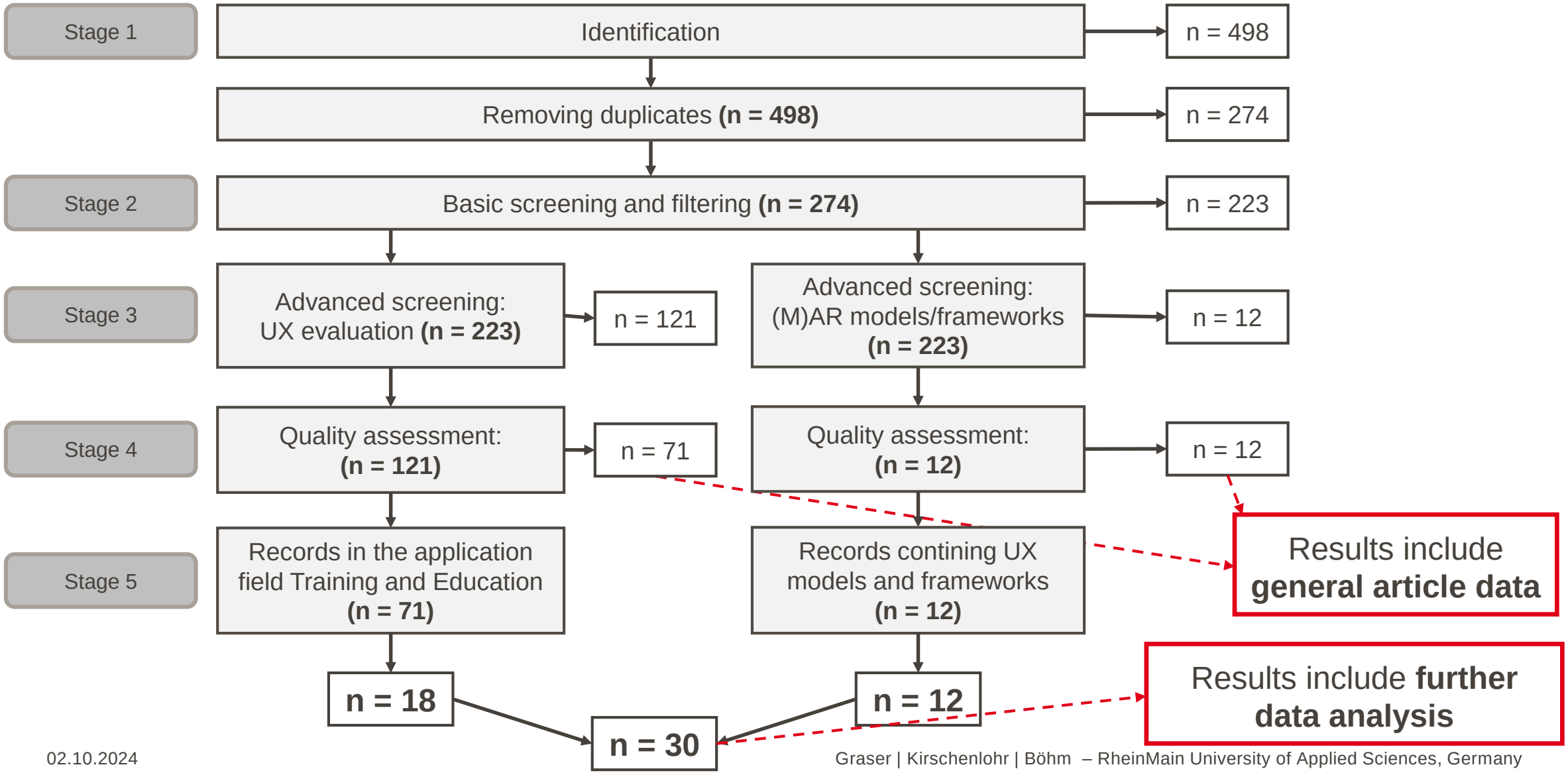

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PUBLICATION YEAR

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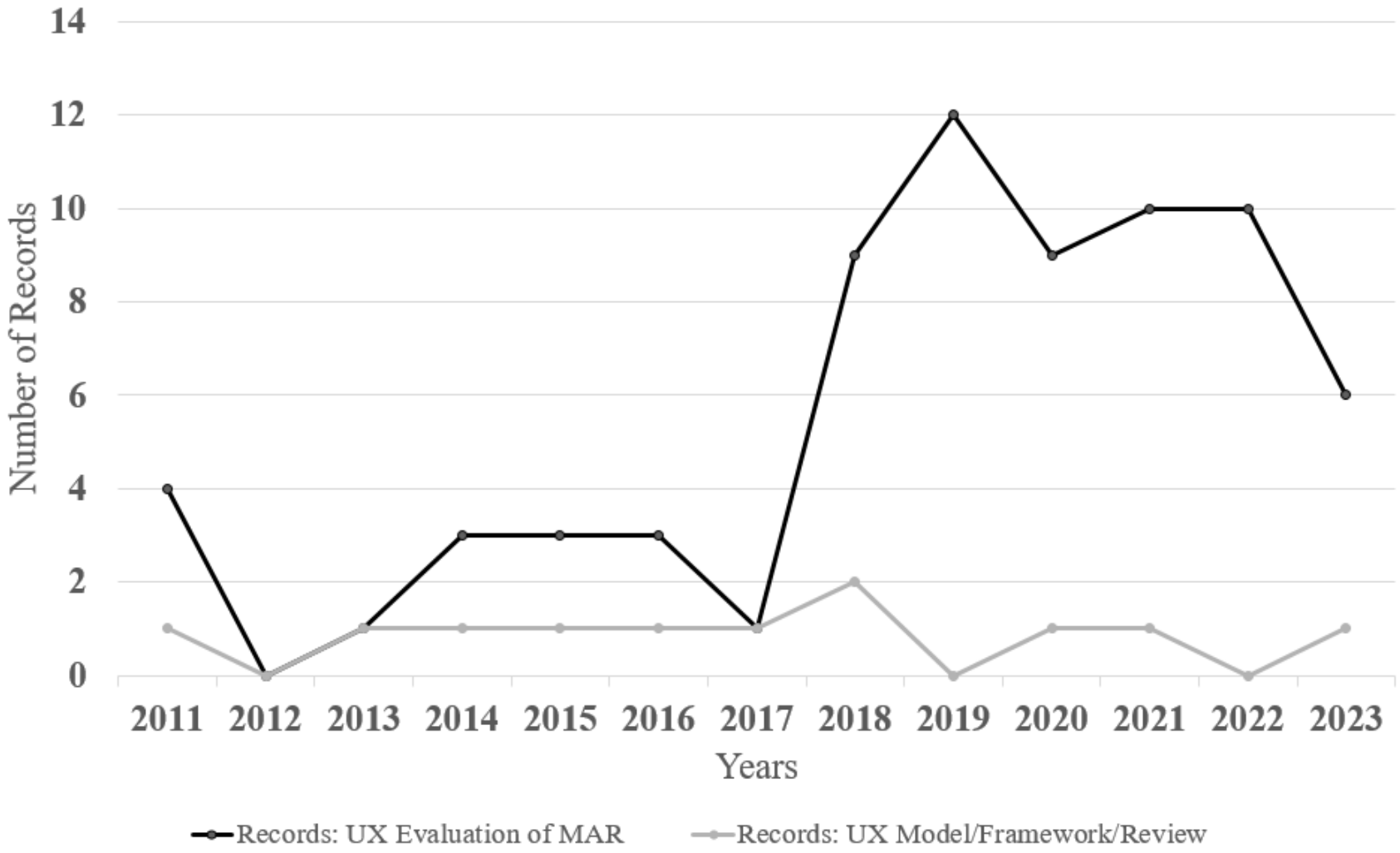
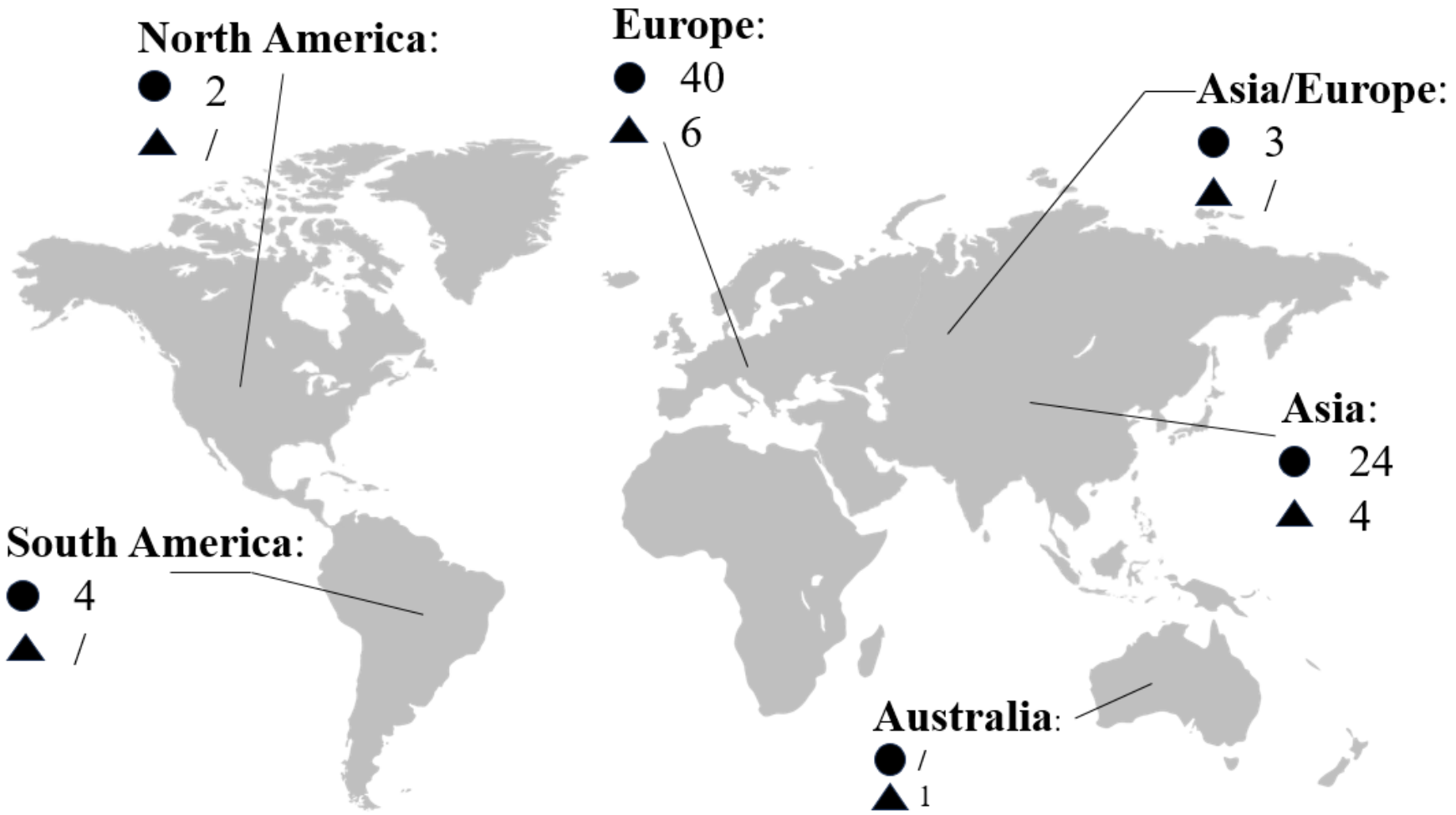


ORIGION


North America:
2
/
Europe:
40
6
Asia/Europe:
3
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Asia:
24
4
South America:
4
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Australia:
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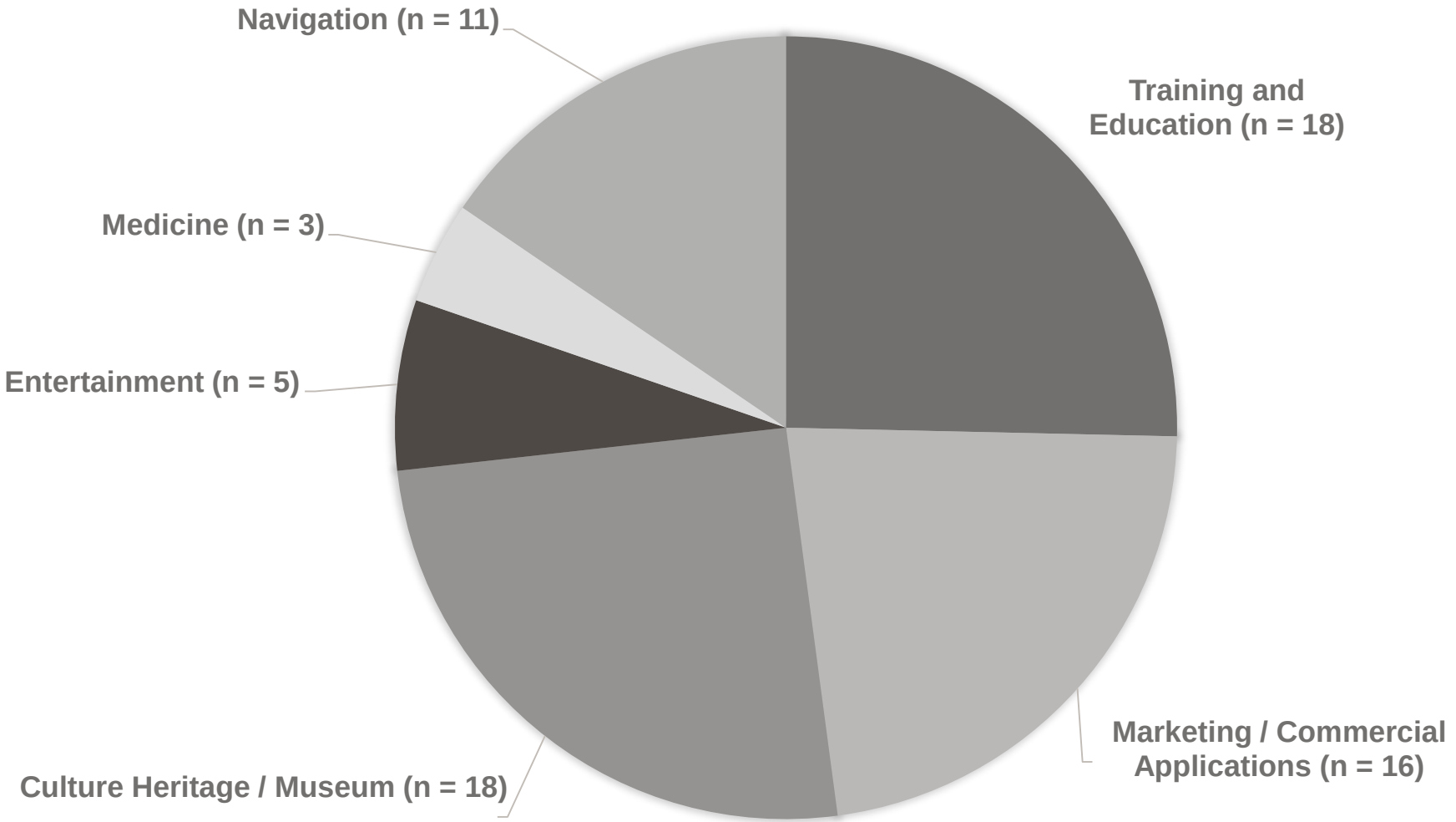
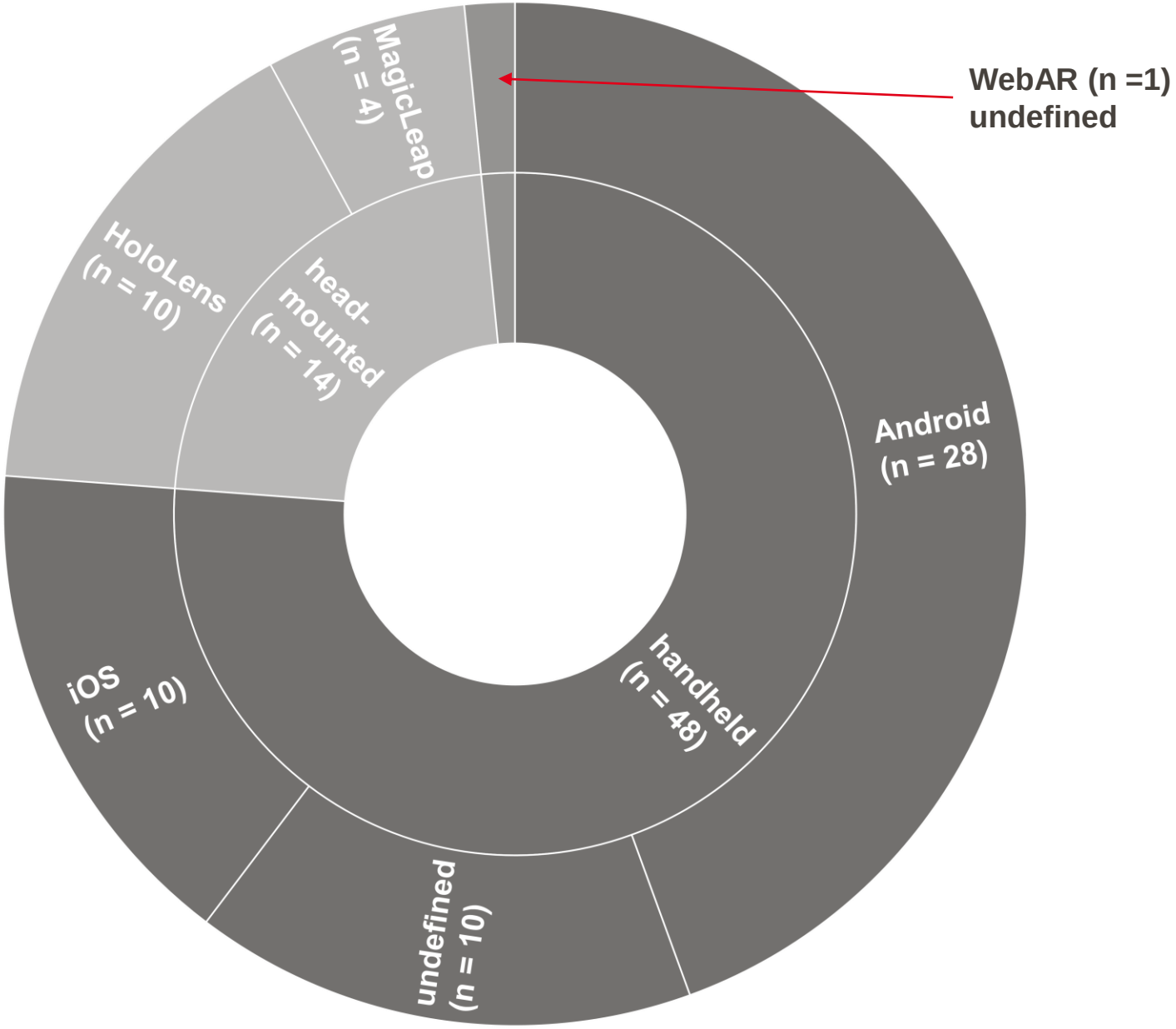
1
Records: UX Evaluation of MAR with Quality Assessment
Records: UX Model/Framework/Review

APPLICATION FIELD



APPLICATION DEVICE: HARDWARE & SOFTWARE



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Software

→ Not specified for 43 articles

→ ***Unity*** as most commonly used platform

→ Extended by ***PlugIns*** & ***own programming***

unity

+

METHODOLOGICAL APPROACH

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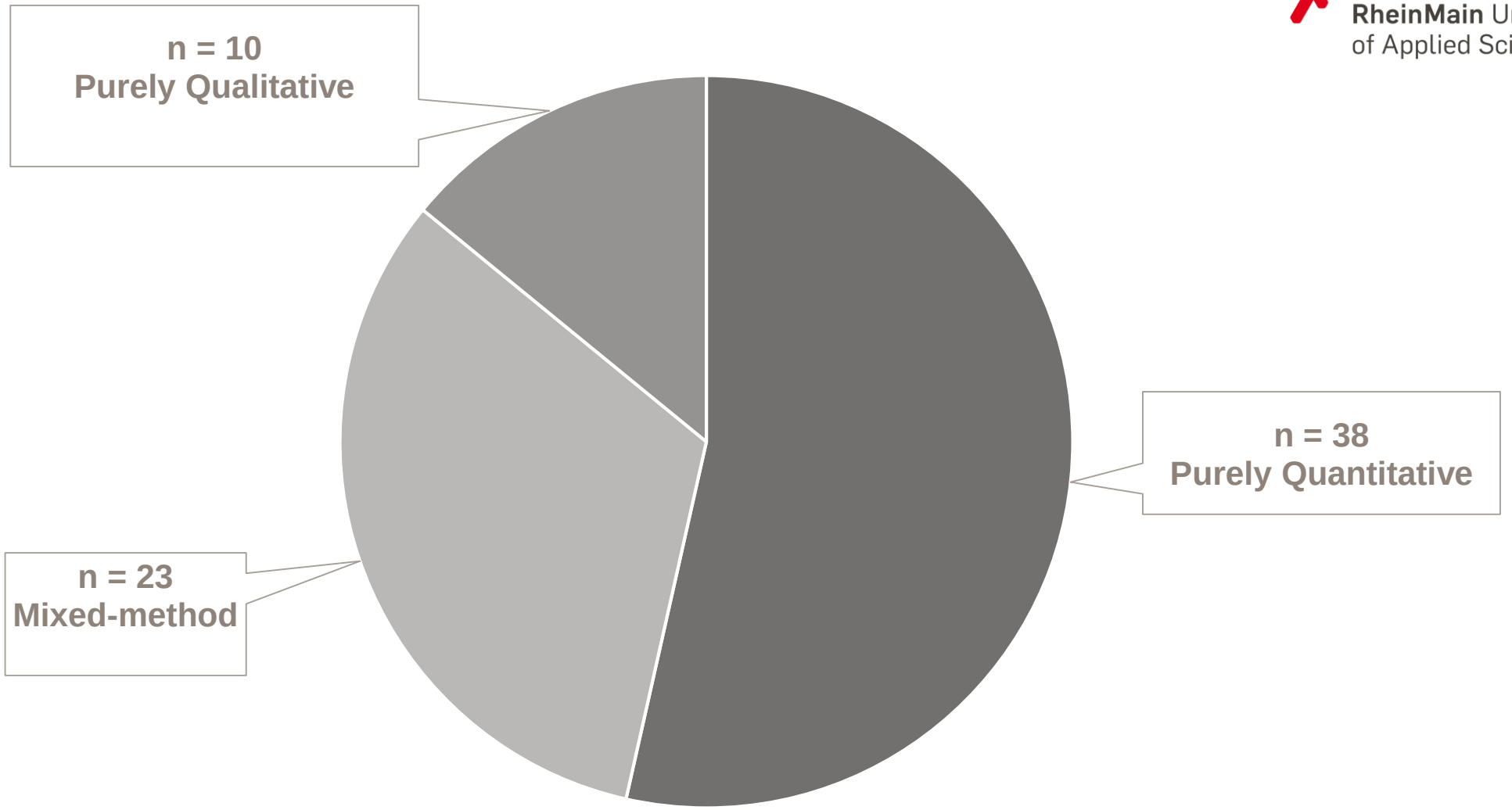
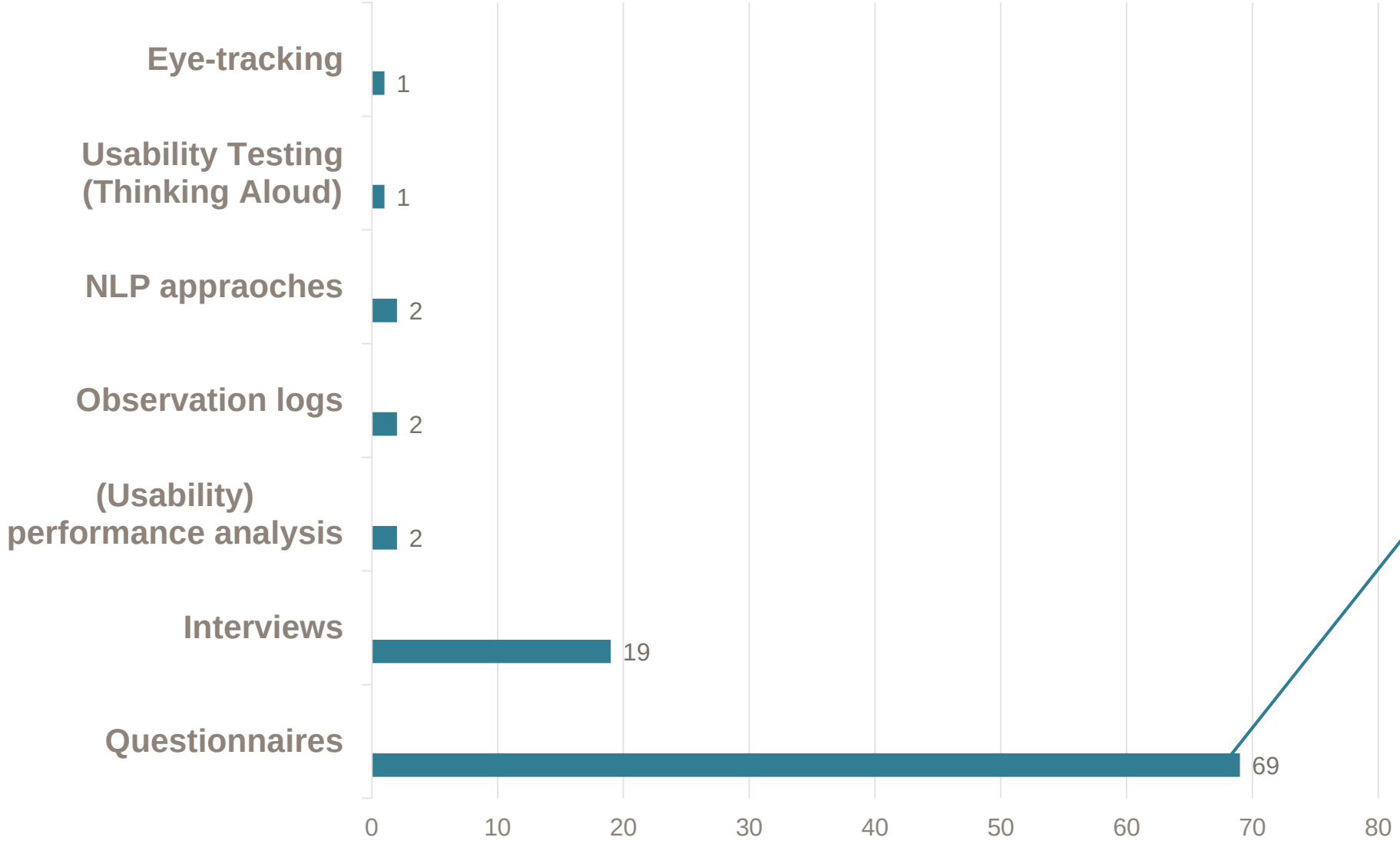


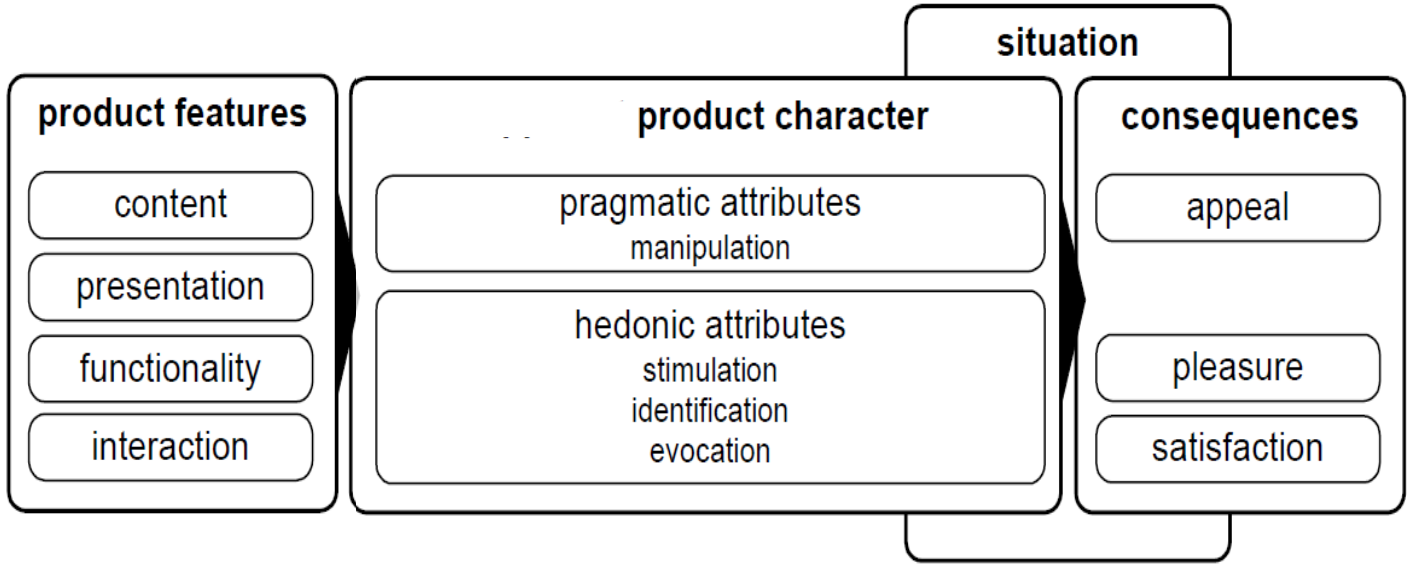
EVALUATION METHODS



- **UEQ (n = 10)**
- **SUS (n = 8)**
- **QUIS**
- **AttrakDiff**
- **SSQ**
- **NASA-TLX**
- **TPI**
- **HARUS**
- **PSSQU**
- **TAM**
- **UTAUT**

UX MODELS & FRAMEWORKS

- Six conceptual, theoretical models/frameworks
- Different focus among the models/frameworks
- No UX AR model as common foundation
- General UX model of Hassenzahl (2003) as common foundation



AR-SPECIFIC UX-QUESTIONNAIRES

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	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*

EVALUATION RESULTS IN TRAINING AND EDUCATION

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- Mostly quantitative evaluation results
- Both pragmatic and hedonic qualities are predominantly evaluated as positive from a UX perspective
- Negative evaluation results refer problems, deficiencies, and errors with the functionality and features of the AR system
- Mostly first-time users
- No cumulative evaluation over time
- No insights into systematic improvement of applications and re-evaluation
- Overall, AR has been perceived as positive providing a benefit

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DISCUSSION & IMPLICATIONS

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RQ1: *Which methods were applied for measuring UX in the context of AR?*

- No established method measuring the UX for AR in the field of Training and Education could be identified
- No AR-specific UX questionnaire for the field of Training and Education could be identified
- Mostly quantitative measurement (followed by mixed-method)

DISCUSSION & IMPLICATIONS

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RQ2: *What theoretical models and frameworks exist concerning UX and AR?*

- Six theoretical models/frameworks exist
- No model/framework refers to the field Training and Education
- UX model by Hassenzahl (2003) as common foundation in UX research

DISCUSSION & IMPLICATIONS

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RQ3: *What results were conducted in UX research regarding AR in the domain of training and education?*

- Both pragmatic and hedonic qualities are predominantly evaluated as positive from a UX perspective
- Negative evaluation results refer to errors and deficiencies regarding the system or functionality
- Lack of reference to specific improvement suggestions for developers
- Researchers should focus on establishing error-free systems
- Introduction to AR for first-time users

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Further Topics

UX Evaluation and Learning Effect:

- Previous research has considered both separately
- Few studies describe the relationship qualitatively
- Only one study computed the correlation between UX and Learning Effect
- Lack of research regarding the statistical relationship between both

UX Evaluation and Generative Artificial Intelligence (GenAI):

- No UX evaluations of AR applying GenAI
- Great potential to (1) enhancing, (2) support, and (3) automate UX research activities by applying LLMs among the research process

OUTLOOK AND FUTURE RESEARCH

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- SLR provides a **comprehensive overview** concerning **literature of UX of AR in Training and Education** domain
- **Specific research gaps could be identified**
- **Further relevant research topics were declared**

THANK YOU FOR YOUR ATTENTION!

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Connect!

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