

Personalizing User Interfaces of Large Interactive Displays for Intercultural Groups in Semi-Public Areas

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Abstract

Technology in ubiquitous areas, such as large interactive displays replacing non-digital information boards, addresses diverse user groups with individuals, each with unique design preferences shaped by their cultural background. While personalization focusing on culturally based preferences has been shown to enhance usability and user experience for single-user applications, its implementation in shared user interfaces remains challenging. This thesis investigates how large interactive displays as multi-user applications can be personalized by considering a group's intercultural design preferences for the user interface design and how this approach influences the user experience.

Therefore, the overarching aim is to develop a personalization approach for large interactive displays in semi-public areas, focusing on intercultural adaptation of key user interface aspects to enhance the user experience. Key challenges include identifying the most suitable group modeling strategy for merging cultural design preferences and investigating ways to adapt key user interface aspects of large interactive displays.

The thesis systematically develops its solution following Peffers et al.'s approved Design Science Research methodology. The developed personalization approach consists of a five-step procedure, ontologies (for group modeling and user interface adaptations), and a system architecture, ensuring a structured implementation. It is demonstrated by implementing it for the CommunityMirrors and evaluated through a mixed method laboratory study involving 24 participants randomly assigned to four groups. The study compared two group modeling strategies for merging cultural user profiles, average without misery and fairness, and investigated the impact on user experience. The participants evaluated three user interfaces during think-aloud sessions, rating each version with the UEQ-S, and compared them during a semi-structured interview, generating over 18 hours of video and audio material. A coding analysis of the interview transcripts revealed interesting findings and improvements.

The study determined the group modeling strategy fairness as the most successful for aggregating cultural user profiles. While the user interface based on the average without misery strategy also outperformed the baseline version, its strict threshold excluded some user preferences, reducing its effectiveness. Overall, the adapted user interfaces, especially those based on the fairness strategy, positively impacted the user experience, with a substantial impact on the pragmatic quality, as shown by the UEQ-S. While the personalization approach aims minimizing active user involvement, the evaluation revealed that user interface aspects with strong interdependencies with others, e.g., "density" in this case, benefit from being customizable to prevent a negative impact on the user experience. The iteratively improved approach systematically incorporates vital variables for the personalization of large interactive displays in semi-public areas by considering a group's intercultural design preferences.

This work contributes to several research fields within the Human-Computer Interaction community by advancing group-based personalization approaches, benefiting group modeling (group recommender systems), adaptive systems, user interface design, and user experience for ubiquitous technologies. Further, companies interested in deploying large interactive displays in office environments and practitioners focusing on intercultural design challenges may also benefit from these findings.

Zusammenfassung

Ubiquitäre Technologien, wie z. B. große interaktive Displays als Ersatz für nicht-digitale Informationstafeln, werden von diversen Gruppen genutzt. Jede Person hat dabei individuelle Gestaltungspräferenzen, geprägt durch ihren kulturellen Hintergrund. Die Personalisierung auf kulturell-bedingte Präferenzen verbessert nachweislich die Usability und User Experience für Single-User-Anwendungen. Jedoch bleibt der Transfer auf gemeinsam genutzte Benutzerschnittstellen (User Interfaces) eine Herausforderung.

Diese Arbeit untersucht, wie große interaktive Displays als Multi-User-Anwendungen im halböffentlichen Raum, personalisiert werden können. Das Ziel ist die Entwicklung eines Personalisierungsansatzes, der sich auf die interkulturelle Anpassung von Kernaspekten des User Interface konzentriert, um die User Experience zu verbessern. Zu den wichtigsten Herausforderungen gehören die Identifizierung der am besten geeigneten Gruppenmodellierungsstrategie für die Aggregation kultureller Gestaltungspräferenzen und die Untersuchung von möglichen Anpassungen der Kernaspekte des User Interfaces.

Die Lösung wurde systematisch nach der Design Science Research-Methodik von Peffers et al. entwickelt. Der Personalisierungsansatz umfasst eine fünfstufige Vorgehensweise, Ontologien (für die Gruppenmodellierung und die Anpassung des User Interface) und eine Systemarchitektur, die eine strukturierte Implementierung gewährleisten. Die Implementierung und Evaluation erfolgte anhand der CommunityMirrors-Anwendung in einer Mixed-Methods-Laborstudie mit 24 zufällig in vier Gruppen eingeteilten Teilnehmern. Die Studie verglich zwei Gruppenmodellierungsstrategien zur Aggregation kultureller Nutzerprofile, Average without Misery und Fairness, und untersuchte die Auswirkungen auf die User Experience. Die Teilnehmer testeten drei User Interfaces in Think-Aloud-Sessions, bewerteten sie mit dem UEQ-S und verglichen sie in einem semi-strukturierten Interview. Dies führte zu über 18 Stunden Video- und Audiomaterial. Eine Coding-Analyse der Interviewtranskripte ergab interessante Erkenntnisse und Verbesserungen.

Die Studie zeigte, dass die Gruppenmodellierungsstrategie Fairness am erfolgreichsten für die Aggregation von kulturellen Nutzerprofilen ist. Auch das User Interface, das auf der Strategie Average without Misery basiert, übertraf die Basisversion, schloss aber durch den Threshold einige Nutzerpräferenzen aus, was die Effektivität minderte. Insgesamt wirkten sich die angepassten User Interfaces, insbesondere die auf Fairness-basierenden, positiv auf die User Experience aus, mit einem erheblichen Einfluss auf die pragmatische Qualität, wie der UEQ-S zeigt. Während der Personalisierungsansatz darauf abzielt, die Beteiligung des Nutzers zu minimieren, zeigte die Evaluation, dass Aspekte des User Interface mit starken Abhängigkeiten, wie z.B. Dichte in diesem Fall, davon profitieren, anpassungsfähig zu sein, um einen negativen Einfluss auf die User Experience zu verhindern. Der iterativ verbesserte Ansatz berücksichtigt systematisch wichtige Variablen, die die Personalisierung großer interaktiver Displays im halböffentlichen Raum beeinflussen, indem er die interkulturellen Designpräferenzen einer Gruppe berücksichtigt.

Dieses Ergebnis leistet einen Beitrag zu mehreren Forschungsbereichen innerhalb der Mensch-Computer-Interaktion, indem es gruppenbasierte Personalisierungsansätze voranbringt, die für die Gruppenmodellierung (Group Recommender Systems), adaptive Systeme, das Design von User Interfaces und die User Experience für ubiquitäre Technologien relevant sind. Des Weiteren können Unternehmen, die große interaktive Displays in Büros einsetzen wollen, sowie Praktiker, die sich mit interkulturellen Designherausforderungen beschäftigen, von diesem Ergebnis profitieren.

Sažetak

Sveprisutne tehnologije, poput velikih interaktivnih zaslona kao zamjene za nedigitalne informacijske ploče, koriste različite skupine korisnika. Svaka osoba ima individualne preferencije dizajna, oblikovane njezinom kulturnom pozadinom. Personalizacija prema kulturno uvjetovanim preferencijama dokazano poboljšava upotrebljivost (usability) i korisničko iskustvo (User Experience) za aplikacije s jednim korisnikom. Međutim, prijenos ovog pristupa na zajednički korištena korisnička sučelja (User Interfaces) ostaje izazov.

Ovaj rad istražuje kako se veliki interaktivni zasloni mogu personalizirati kao multi-korisničke aplikacije u polujavnom prostoru. Cilj je razviti pristup personalizaciji koji se fokusira na interkulturalno prilagođavanje ključnih aspekata korisničkog sučelja kako bi se poboljšalo korisničko iskustvo. Ključni izazovi uključuju identifikaciju najprikladnije strategije modeliranja skupine za agregaciju kulturnih preferencija dizajna te ispitivanje mogućih prilagodbi ključnih aspekata korisničkog sučelja.

Rješenje je sustavno razvijeno prema metodologiji Design Science Research prema Peffersu i suradnicima. Pristup personalizaciji obuhvaća petostupanjski postupak, ontologije (za modeliranje skupina i prilagodbu korisničkog sučelja) te sustavnu arhitekturu koja omogućuje strukturiranu implementaciju. Implementacija i evaluacija provedene su putem aplikacije CommunityMirrors u laboratorijskoj studiji s mješovitim metodama (Mixed-Methods), u kojoj je sudjelovalo 24 sudionika, nasumično podijeljenih u četiri skupine. Studija je uspoređivala dvije strategije modeliranja skupina za agregaciju kulturnih korisničkih profila, Average without Misery i Fairness, te ispitala njihov utjecaj na korisničko iskustvo. Sudionici su testirali tri korisnička sučelja u Think-Aloud sesijama, ocjenjivali ih putem UEQ-S i uspoređivali u polustrukturiranom intervjuu. To je rezultiralo s više od 18 sati video i audio materijala. Kodirajuća analiza transkripata intervjuja donijela je zanimljive uvide i poboljšanja.

Studija je pokazala da je strategija modeliranja skupina Fairness najuspješnija za agregaciju kulturnih korisničkih profila. Korisničko sučelje temeljeno na strategiji Average without Misery također je nadmašilo osnovnu verziju, no zbog primjene praga (threshold) isključivalo je neke korisničke preferencije, čime je smanjena učinkovitost. Općenito, prilagođena korisnička sučelja – osobito ona temeljena na strategiji Fairness – pozitivno su utjecala na korisničko iskustvo, s značajnim učinkom na pragmatičnu kvalitetu, što je potvrđeno kroz UEQ-S. Lako je pristup personalizaciji usmjeren na minimiziranje korisničkog angažmana, evaluacija je pokazala da neki aspekti korisničkog sučelja, koji imaju snažne međuovisnosti (npr. gustoća prikaza), imaju koristi od prilagodljivosti kako bi se spriječio negativan utjecaj na korisničko iskustvo. Iterativno poboljšani pristup sustavno uzima u obzir ključne varijable koje utječu na personalizaciju velikih interaktivnih zaslona u polujavnom prostoru, prilagođavajući ih interkulturalnim preferencijama dizajna određene skupine korisnika.

Ovo istraživanje doprinosi brojnim znanstvenim područjima unutar interakcije čovjeka i računala (HCI) unapređujući grupno utemeljene pristupe personalizaciji, korisne za grupno modeliranje (Group Recommender Systems), adaptivne sustave, dizajn korisničkog sučelja i korisničko iskustvo u sveprisutnim tehnologijama. Osim toga, rezultati mogu koristiti tvrtkama koje žele implementirati velike interaktivne zaslone u uredskim prostorima, kao i praktičarima koji se bave interkulturalnim izazovima u dizajnu.

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Abbreviations

General Terms

ABIS	Adaptivität und Benutzermodellierung in bestimmten Softwaresystemen
CSCW	Computer-Supported Cooperative Work
CSV	comma-separated values
DB	Database
e.g.	exempli gratia
HCI	Human-Computer Interaction
ID	Identification
ISO	International Organization for Standardization
IT	Information Technology
JavaFX	Java special EFF-ECTS
NaN	Not a Number
OWL	Ontology Web Language
OWLGrEd	Graphical Ontology Editor
PDA	Personal Digital Assistant
QR	Quick Response
RFID	Radio Frequency Identification
REQ	Requirement
RQ	Research Question
SD card	Secure Digital Card
UEQ(-S)	User Experience Questionnaire (Short)
UI	User Interface
UML	Unified Modeling Language
UX	User Experience
VR	Virtual Reality
XR	Extended Reality

Cultural Dimensions (Hofstede)

CD	Cultural Dimension
IDV	Individualism vs. Collectivism
IND	Indulgence vs. Restraint
LTO	Long-term vs. Short-term Orientation
MAS	Masculinity vs. Femininity
PD	Power Distance
UA	Uncertainty Avoidance

Evaluation Terms

avg	average
avg w/o mis.	average without misery
B	Baseline
fai	fairness
UK	United Kingdom
USA	United States of America
V1	Version 1
V2	Version 2

Outline of the Thesis

Part I: Introduction and Theory

CHAPTER 1: INTRODUCTION

This chapter introduces the motivation and research gap addressed by this thesis. It discusses the research questions to be answered about personalizing large interactive displays for intercultural groups in semi-public areas. Also, it provides an overview of the methodology applied in this context and its scientific contribution.

CHAPTER 2: FUNDAMENTALS

To build a common ground, this chapter introduces fundamental definitions of terms vital for understanding this research. Further, cultural dimension models, typically used to describe societal cultural differences, are presented and discussed.

CHAPTER 3: RELATED WORK

This chapter provides an overview of related work that contributes to and motivates this thesis' idea and objectives. It includes prior research regarding examples of culture impacting the usability and user experience, summarizing cultural design differences, and how various research fields handle diverse (design) preferences, e.g., in international interface design, marketing, adaptive systems, or group recommender systems.

Part II: Design and Development

CHAPTER 4: REQUIREMENTS ANALYSIS

Several aspects are relevant when personalizing a user interface that considers diverse design preferences of an intercultural group. This chapter summarizes requirements from various perspectives for such a system, including contextualizing the display, identifying culturally relevant key user interface aspects, and their adaptations. Also, common group modeling strategies and their application to cultural dimension values are discussed. Finally, all identified requirements for the personalization approach are summarized.

CHAPTER 5: AN APPROACH TO INTERCULTURAL PERSONALIZATION OF LARGE INTERACTIVE DISPLAYS

This chapter derives a personalization approach for user interfaces of large interactive displays used by an intercultural group in semi-public areas. It includes a five-step procedure with a detailed explanation of implementing such an adaptive system and, to improve understanding further, ontologies for group modeling and user interface adaptations, such as a system architecture that incorporates all relevant components and their relations for the personalization approach. Also, an overview of the proposed approach is provided, and ambiguities are summarized, which still need clarification.

Part III: Evaluation

CHAPTER 6: EVALUATION OVERVIEW

This chapter introduces the evaluation of the personalization approach by providing vital information about the study design, the methodologies applied, general conditions, the procedure, and an overview of the data collection. This contextual and detailed information is vital for correctly understanding and interpreting the following chapters.

CHAPTER 7: APPLICATION-SPECIFIC IMPLEMENTATION

The application-specific implementation analyzes whether the proposed approach considers all relevant aspects for intercultural personalization of large interactive displays. Therefore, the personalization approach presented in Chapter 5 is interpreted and transferred to the CommunityMirrors application. Making this more transparent, the application is described and introduced in detail, such as an application-specific system architecture. This is followed by an in-depth example of implementing the five-step procedure for CommunityMirrors.

CHAPTER 8: RESULTS

Based upon the application-specific implementation, the results derived from the verification and evaluation of the personalization approach are discussed in this chapter. Therefore, the analysis of the evaluation outcome is described in detail. Consequently, the results are discussed concerning the comparison of two group modeling strategies, average without misery and fairness, such as the results of the personalization approach's impact on the user experience.

Part IV: Research Findings and Conclusion

CHAPTER 9: INTERCULTURAL PERSONALIZED USER INTERFACE DESIGN

This chapter discusses the evaluation's results and summarizes them in the research findings. These are further incorporated into an iteratively improved personalization approach considering the evaluation's insights. Finally, the limitations concerning the overall personalization approach and its evaluation are discussed in detail.

CHAPTER 10: CONCLUSION

In the final chapter, a line is drawn between the motivation, the research questions posed, and the outcome of this research within the summary. Based on this summary, the contributions and implications of this work are discussed in detail. This also includes an in-depth explanation of transferring these research outcomes to other domains and real-world scenarios. Potential research projects building upon this thesis are discussed in future work, which are then concluded by a closing remark.

Part I.

Introduction and Theory

1. Introduction

Technology has the potential to connect people worldwide in daily situations. It has become an integral part of our lives, shaping interactions in both personal and professional settings. It is almost unfeasible to encounter society without using technology, especially smartphones as our constant companions, wearables that are even permanently attached to our bodies, and technology that we encounter in ubiquitous areas such as vending machines, paying digitally for groceries, and large displays that entertain us while waiting for the next metro. Also, technology is widely used in work environments: It enables working from home and collaborating with colleagues worldwide, which reduces travel expenses for companies, etc. Primarily used are personal devices such as laptops, smartphones, or tablets. However, in spatial work environments, technology has become more and more prevalent, especially to foster knowledge exchange: large displays showing the current progress of the agile software development team, canteen plans shown when heading to lunch, or large displays as digital solutions replacing old posters and information boards. These digital solutions are essential to smart cities and modern work environments but encounter new challenges: The technology is used by several people, either simultaneously or sequentially. Unlike personal devices, which can be tailored to an individual's preferences, large interactive displays must accommodate a broad audience with varying cultural backgrounds and interaction habits. This, in particular, is influenced by the design of the user interfaces (UI).

In work environments such as office buildings, the coffee corner of a department, etc., it would be fascinating to place a large interactive display that enhances the knowledge exchange within the company by displaying relevant information about who is working in related departments, what they are working on, what their expertise is, and current activities in the company and other departments from a professional perspective. People in such office areas and visitors can explore the information this display provides through touch interactions or observations. This enables finding interesting content or other employees with similar interests outside traditional information systems. Users generally engage with these displays passively or by browsing rather than performing complex tasks or manual data entry. This distinction is vital for UI design, highlighting the need for intuitive, visually driven interaction models rather than interfaces dependent on detailed textual input, as such displays have great potential to raise awareness [129] and contribute to the social exchange in companies. It is essential to consider the design preferences of users in the display's surroundings as they are community-shared devices. Considering the group's design preferences is a personalization approach for such UI to enhance and improve user interactions. Therefore, consolidating multiple diverse design preferences is a challenge that has not been deeply explored. However, as technology becomes more integrated into our daily lives, the data it collects grows in importance and presents new opportunities for use.

In many modern societies, intercultural user groups are the norm rather than the exception, particularly in shared spaces such as metro stations, office buildings, and public institutions. People from all over the world work together in departments, bringing with them UI design preferences often shaped by their cultural background, sometimes without conscious awareness. It is widely recognized that culture impacts the user experience and usability. Consequently, it should be considered in UI design, as our cultural backgrounds subtly affect our interaction habits, often without our conscious knowledge, whether as users or designers [220]. Understanding cultural influences is critical for UI design, particularly in building user-friendly interfaces. These differences in what various cultures perceive as good user experience are widely explored, and new findings are gathered regularly, e.g., [13, 33, 78, 80]. This is particularly true for single-user interfaces, where tailoring the UI to the user's cultural background can considerably improve usability and satisfaction [13, 15, 33, 188, 203].

Current research focuses on improving the UI for an individual user or based on specific user characteristics, e.g., a particular culture, gender, age, etc. In contrast, ubiquitous technologies, such as large interactive displays in semi-public areas [114], address groups of users with diverse cultural backgrounds, more precisely, intercultural user groups. Unlike single-user personalization, the UI design for these groups must consolidate individual cultural design preferences into intercultural preferences, ensuring a cohesive and inclusive user experience.

This thesis addresses this gap by investigating how to personalize large interactive displays for intercultural groups in semi-public areas. It has excellent potential, as it only requires gathering data about the cultural background of frequent users within the vicinity of the display location, simplifying the personalization process by avoiding real-time user identification that is restricted by data privacy regulations. Also, real-time personalization of single users in front of such a display would solely consider that particular user's preferences, despite multiple ones. In addition, the focus on the intercultural design preferences of a group also targets deep-rooted ones that may be unconsciously prevalent for some but strongly impact their experience and interactions with such displays, as it is not apparent for most people how exactly their cultural background affects them [157, 158]. Consequently, this work explores the potential and approaches to personalize large interactive displays for intercultural groups in semi-public areas.

The core parts of this thesis are (1) large, interactive, semi-public displays, (2) intercultural groups, and (3) personalization. For better understanding, Figure 1.1 displays how these components are interconnected:

- (1) Large, Interactive, Semi-Public Displays:** A large, interactive, non-personal technical device that targets improving knowledge exchange and communication within intercultural user groups in semi-public areas. Its UI design is interculturally personalized for this group to increase the user experience and consequently support the knowledge exchange by fostering interactions.
- (2) Intercultural Groups:** A group of people with diverse cultural backgrounds who share a common space, such as a semi-public area or a workplace. This thesis focuses on intercultural groups interacting with large interactive displays to access information and

connect with colleagues across departments. Each individual has unconscious UI design preferences shaped by their cultural background. To personalize the UI design of such displays, these individual preferences are aggregated to derive intercultural UI preferences for the group.

- (3) **Personalization:** Tailoring the UI of large interactive displays in semi-public areas to the preferences of the intercultural user groups leads to an increasing user experience and, subsequently, more interactions with the displays.

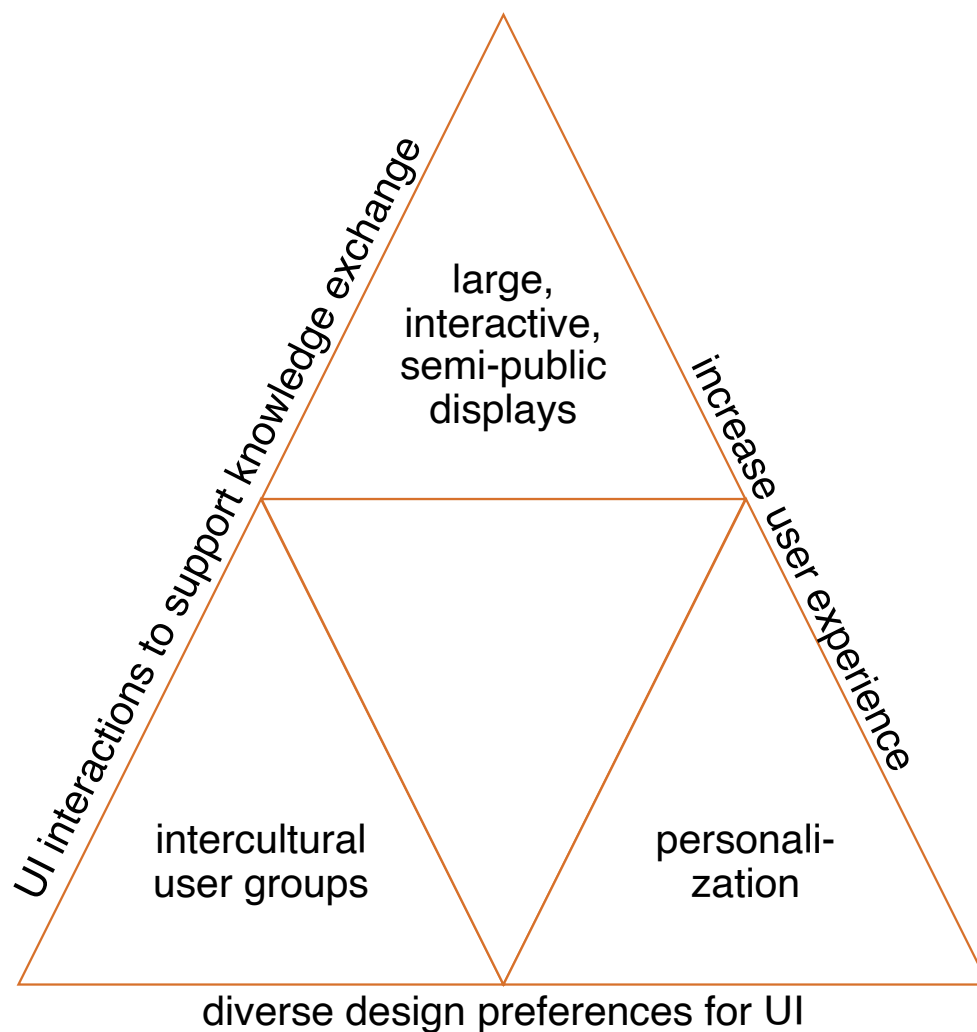


Figure 1.1.: Bridge terms for the relations between the key components of this work.

The relations and impacts between these key components define the scope and are essential to this work. The following sections will describe the research questions and the methodology used to answer them, including the contribution of this work.

1.1. Research Questions

Users perceive the UI design of large interactive displays in semi-public areas differently based on their cultural background. To enhance user experience, the UI design of such displays must incorporate the intercultural design preferences of the group. Therefore, the potential to address these intercultural preferences to personalize the UI of large semi-public displays will be explored. This leads to the following overarching research question (RQ):

RQ: How can intercultural preferences regarding the UI design of large interactive displays in semi-public areas be considered, and how does that impact the user experience?

The objective is to develop a personalization approach that enables the intercultural personalization of such devices by considering intercultural design preferences and explaining how such personalization can be implemented. Additionally, it determines the impact on user experience. To address this research question in depth, this thesis investigates these two key aspects:

RQ1: Which aggregation methods are suitable to model intercultural group preferences regarding UI design?

Personalization technologies rely on user models that incorporate users' preferences. In this context, a group model is essential for capturing the group's design preferences. Therefore, this work explores how to derive these intercultural design preferences by analyzing group modeling strategies and identifying those most effective in handling cultural dimension values for UI personalization.

RQ2: What are key UI aspects of large interactive displays in semi-public areas most relevant for intercultural personalization, and how should they be personalized?

It is crucial to identify which UI aspects are culturally relevant for large interactive displays and to determine how they should be personalized. As existing research primarily focuses on single-user applications, these findings must be validated for shared, large, interactive displays. It determines which UI aspects are most relevant for the intercultural personalization of such displays and how they should be tailored according to cultural dimension values.

By answering these sub-research questions, this thesis generates key insights that form the basis for answering the overarching research question and developing a profound personalization approach for the intercultural UI design of large interactive displays in semi-public areas.

1.2. Scientific Contribution

The fields of interest related to this work are ubiquitous computing, group modeling (from group recommender systems and adaptive systems), Computer-Supported Cooperative Work (CSCW), and personalization. All these topics are related to the research field of Human-Computer Interaction (HCI), which is defined as:

“[...] a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them.” [85]

Within ubiquitous computing, this work examines one specific artifact of interest in smart cities: large interactive displays in semi-public areas, which have a UI shared by several users simultaneously or sequentially. The findings regarding an (inter)culturally sensitive design by personalizing the UI are insightful for researchers, operators, and funders of smart city technology. The approach will support increasing the interaction with such devices by considering the intercultural design preferences of a group. However, the results of this work mainly focus on work environments (semi-public), where it is much easier to gather information about the users to support knowledge exchange by increasing awareness about the departments and company, which is related to the field of CSCW. Transferring the results to the public space will require adjustments to the proposed personalization approach, especially concerning the data acquisition of potential users. This work also suggests ideas for conducting this (Section 10.2).

Developing a UI design for these devices personalized to a culturally diverse user group contributes to group recommender systems, especially within the subtopic of group modeling preferences. Investigating various strategies for aggregating (design) preferences is a fascinating contribution to this research field, as comparing aggregation strategies and applying them to different contexts, besides standard numeric ratings, is rare but essential. The phenomenon of shared UI will always be a part of future developments within the area of HCI or Human-Machine Interaction, as common ground is required to ensure successful communication about the things users see in shared UI [82].

Further, the personalization of ubiquitous technology is another essential field of interest benefiting from this work. The in-depth discussion of personalizing large interactive displays in semi-public areas summarizes the challenges and potentials vital for designing similar devices within such areas. Also, personalizing the UI for a group of people rather than a single user is highly important in this context. This work supports the personalization objectives of shared UI that aim to consider and become more aware of culturally derived design differences and preferences. Users and designers often overlook this aspect due to the unconscious impact of our cultural background on technology perception. This work derives insights regarding the impact of intercultural personalization on the user experience with ubiquitous devices. It points out what UI aspects are most relevant, the relations between UI aspects, and whether and how personalizing the UI aspects impacts the user experience positively or negatively.

1.3. Research Methodology

Understanding and implementing intercultural personalization of large interactive displays requires a structured approach that integrates problem analysis, iterative design, and evaluation. This research aims to explore how intercultural design preferences influence UI design and to develop a validated personalization approach to address this challenge. Given this, the Design Science Research methodology by Peffers et al. [178] provides an appropriate and well-established framework that emphasizes the systematic development and evaluation of artifacts to address identified problems. As an overview, Figure 1.2 displays how the Design Science Research approach aligns with this work's research questions and objectives.

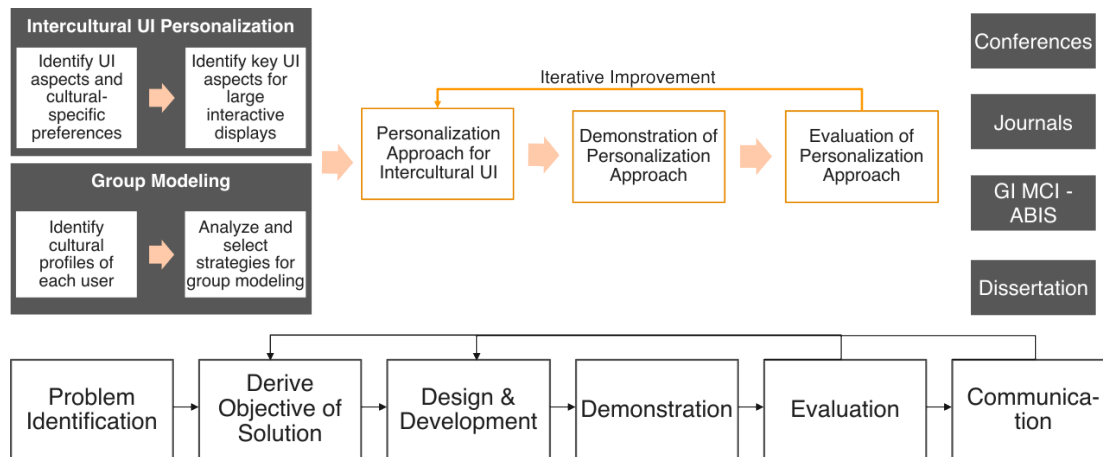


Figure 1.2.: Overview of the Design Science Research methodology by Peffers et al. [178] and the corresponding research questions and objectives.

The problem statement and motivation (see Section 2.1, Chapter 3) are derived primarily from a literature analysis of cultural differences in UI design, their impact on usability and user experience, personalization, and adaptive systems. Previous research [114, 219, 220, 221, 225] has highlighted the lack of cultural personalization in the UI design of large interactive displays.

A literature analysis [220] revealed that a research group investigating large interactive displays in (semi-)public areas derived 52 design recommendations without considering cultural impact and preferences. In this analysis, these design recommendations for the UI design of large interactive displays in semi-public areas were mapped against Hofstede's cultural dimensions [87, 89, 90], demonstrating that they were not tailored to specific cultural needs. This highlights the gap in existing research and the need for more structured decision-making in UI personalization of such devices. Additionally, the challenges and potential of future developments of shared realities in various contexts (e.g., virtual or extended reality (VR, XR)) and their impact on personalization and recommendation systems are discussed in [82], which further determines the necessity of group modeling and considering diverse preferences for shared UI, "shared realities", in future settings. This also underpins this work's relevance.

The Design Science methodology is particularly well-suited for addressing this research gap. It enables systematic development, refinement, and evaluation of a personalization approach that integrates intercultural design preferences while generating new insights into its impact on user experience. The Design Science methodology is followed through these steps:

- Problem identification and literature-based motivation: Chapter 3
- Requirements analysis to structurally consider key aspects in this context: Chapter 4
- Personalization approach development: Chapter 5
- Demonstration through a real-world application prototype: Chapter 6 & Chapter 7
- Evaluation through a laboratory study with qualitative and quantitative methods: Chapter 6
- Final refinement and validation based on study results: Chapter 8 & Chapter 9

Additionally, communication and discussion took place throughout the overall process through conference and journal publications as well as the active participation in the *ABIS specialist group of Gesellschaft der Informatik*¹. The outcome following this Design Science process is documented in this dissertation, summarizing all findings and contributions, while the outline (page xxi) provides an overview of this work. The list below summarizes contributions that emerged during this endeavor:

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¹Adaptivität und Benutzermodellierung in interaktiven Softwaresystemen (<https://fg-abis.gi.de>)

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2. Fundamentals

This chapter defines relevant terms for this thesis, including culture, intercultural, large semi-public displays, personalization, and other related terms. Further, an overview of cultural classification models used to describe cultural differences is provided, along with a discussion of relevance to this work.

2.1. Definitions

This section discusses definitions for essential terms of this thesis. This overview builds a common ground for the underlying work and the following chapters.

2.1.1. Large, Interactive, Semi-Public Displays

This work focuses on personalizing the user interface of large, interactive displays in semi-public areas. To emphasize the peculiarities of this technology, Huang et al. [93] define and describe such displays, as targeted in this work, as

“Wall displays, including vertically oriented free-standing, wall-mounted, and wall-projected configurations, foster a combination of interactive use and passive value. Unlike desktop displays, they offer content visibility from a distance and can therefore benefit users through ambient or opportunistic information even when users aren’t directly in front of the display or actively interacting with it.”

The display is located in a semi-public area and should support collaboration in small groups. These locations are defined as “confined physical space” [94], indicating that access to these displays is restricted to a particular group of known users. Figure 2.1 displays the classification of example applications for such large interactive displays and their relation to locations and group sizes. Relevant for this work are the large interactive displays in private shared spaces, in our case, semi-public areas, for small groups with approximately max. 10 users. Such a display is a technological artifact in ubiquitous computing, defined by Weiser [244] as:

“Ubiquitous computing has as its goal the nonintrusive availability of computers throughout the physical environment, virtually, if not effectively, invisible to the user. Unlike virtual reality, ubiquitous computing will integrate information displays into the everyday physical world. Its proponents value the nuances of the real world and aim only to augment them. And unlike current personal digital assistants, ubiquitous computing will be a world of fully connected devices, with cheap wireless networks;

it will not require that you carry around a PDA, since information will be accessible everywhere.”

Sequentially or simultaneously, several people can use these interactive displays in semi-public areas. This creates a ubiquitous UI shared by multiple people, which means it is a “shared reality” for these user groups [82].

A user interface is defined according to ISO 9421-110 as: “All components of an interactive system (software or hardware) that provide information and controls necessary for the user to accomplish specific tasks with the system.” In this work, the abbreviation UI is used to refer to user interfaces of any kind.

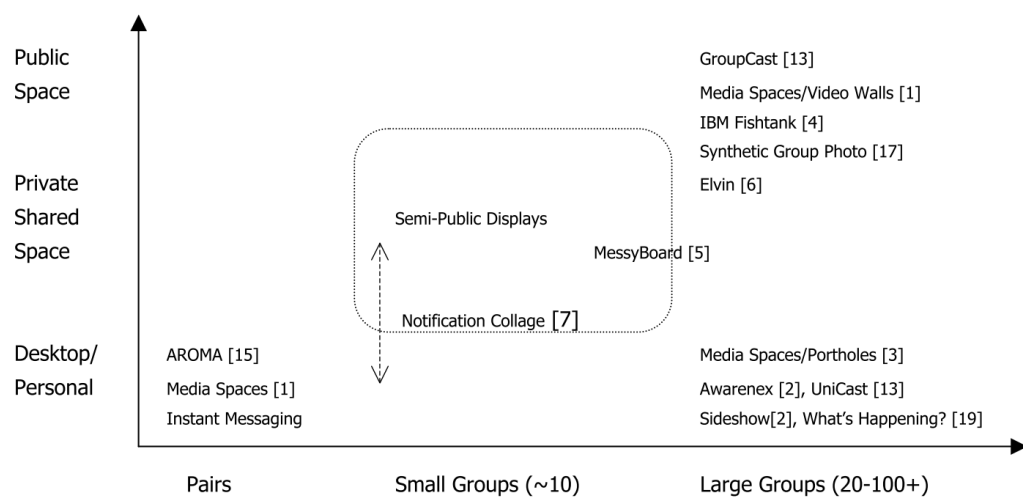


Figure 2.1.: An illustration of the current design space of awareness applications categorized by the group size they are designed to support and the type of space in which they are meant to be viewed. Our design addresses the largely unexplored space of shared public displays to support small, co-located groups, delineated by the box in the central. [94]

2.1.2. Culture, Intercultural, and Cultural Differences

As personalization in this work focuses on preferences derived from the cultural background of users, the terms culture, intercultural, and cultural differences are defined in this section.

Culture

Searching for a definition of “culture” proves to be a great challenge as this term is widely discussed from different points of view and with different granularity. For this thesis, the definition by Röse [197, p. 7] describes the term culture in a technological context, including nationalities as representatives of cultural identities:

“An image of common values, ways of thinking and acting of a group of individuals that contributes to the formation of this community. It influences the interaction with other individuals as well as the interaction with technical devices. The common group values serve as a norm and thus for the orientation of the group members and as differentiation criteria to other groups. The common cultural identity of a group is usually reflected by a nationality.”

Intercultural and Cultural Differences

This work aims to personalize the UI of large interactive displays in semi-public areas for intercultural groups. Such intercultural groups consist of several individuals, each with a different cultural background, which impacts the perception of technology and thus leads to various diverse design preferences. Large interactive displays within ubiquitous computing are supposed to be used by several users, even sometimes simultaneously. Consequently, the intercultural design preferences within groups should be considered by merging individual cultural design preferences. Specifically, “intercultural” was defined by Honold [91] as the result of observing at least two cultures and their differences. For a better classification and description of cultural differences, several researchers from anthropology identified such differences in cultural models. These are discussed in detail in Section 2.2. A related term is “cross-cultural,” which differs from “intercultural,” as discussed in [76]. However, in the context of this work, we focus on the following understanding: While intercultural refers to understanding, negotiating, and integrating differences to gain a shared understanding, cross-cultural focuses solely on comparing and contrasting these differences to focus on a specific culture. To personalize a UI for a group of users, it is necessary to achieve a compromise: A good UI design is a solution that satisfies the whole group’s preferences.

2.1.3. Personalization

The process of achieving a better usability or user experience for an intercultural user group is related to the field of personalization, which is described as “a process that changes the functionality, interface, information access and content, or distinctiveness of a system to increase its personal relevance to an individual or a category of individuals.” [50]. This term can be further distinguished into “adaptability” and “adaptation,” describing different extents of user involvement within the personalization process [50, 172].

2.1.4. Usability and User Experience

The objective of personalizing a UI is related to its positive impact on the usability or user experience. ISO 9241-11 defines usability as “The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use.” Often, usability is measured with task-based evaluations. Large interactive displays in many scenarios are not necessarily task-based but more focused on

pervasive information sharing or fostering CSCW in (semi-)public areas, such as in this work. Subsequently, the user experience of the overall interaction with such a device is more interesting in this particular context. User experience (UX) is defined in ISO 9241-210 as “A person’s perceptions and responses that result from the use and/or anticipated use of a product, system or service.” There is a comprehensive discussion about clarifying the terms “usability” and “user experience” and their interplay [75, 181]. Many studies on cultural differences in UI design focus on improving usability. Even though this work will focus more on UX, prior findings regarding usability are fascinating and essential to building upon.

2.1.5. (Group) Recommender Systems

This section summarizes definitions of recommender systems, user modeling, group recommender systems, and group modeling. These topics are interesting, as the targeted personalization approach focuses on merging cultural user models to achieve a group model, which is a part of group recommender systems.

Recommender Systems

Personalizing the UI of large interactive displays requires knowledge about the users, their cultural background, and their culturally based design preferences. Recommending a UI design belongs to the research field of recommender systems. Such systems suggest items that might be most suitable or enjoyable for a particular user of technologies [23, 191, 192]. An “Item” is the general term used to denote what the system recommends to users. An RS (recommender system) normally focuses on a specific type of item (e.g., movies or news articles) and accordingly, its design, its graphical user interface, and the core recommendation technique used to generate the recommendations are all customized to provide useful and effective suggestions for that specific type of item.” [193] Recommendations are perceived as helpful when being overwhelmed by information or objects to choose from. As cultural preferences are based on cultural backgrounds, their impact on technology perception is not necessarily apparent to users and designers [220], making it an especially relevant application domain.

User Modeling

User modeling is a vital part of recommender systems and describes the process and derivation of preferences for a single user. The definition by Fischer [57] describes user models “[...] as models that systems have of users that reside inside a computational environment. They should be differentiated from mental models that users have of systems and tasks that reside in the heads of users, in interactions with others and with artifacts [...]” Such user models, in the context of this work, cover relevant information about individuals that are then used to compute a cultural user model, representing cultural design preferences [186].

Group Recommender Systems

Recommending an item beyond considering the preferences of a single user, the topic expands into the research field of group recommender systems. Such group recommender systems consider the preferences of multiple users and recommend an item most suitable for a group that consumes this recommendation [51, 143]. Examples of use cases are discussed in Subsection 3.2.4. In particular, large interactive displays are relevant, as “the evolution of computers away from the desktop PC makes it increasingly natural for systems to address groups as well as individuals: Wall displays, information kiosks, [...]” [99]. Already in 2007, group recommendation was identified as an essential aspect of future technologies designed for shared use: “we can expect a continuing growth in the trend toward recommendation (and, more generally, adaptation) to groups of users” [99]. This highlights the importance of this work for the research field of group modeling and group recommendations, deriving UI designs suitable for groups.

Group Modeling

In contrast to user modeling, the success of a group recommendation system relies on the group modeling process, which “combines individual user models to model a group” [143]. Such strategies for group modeling have been derived from Social Choice Theory, essential in group decision-making, introduced in Subsection 3.2.4 and discussed in detail in Subsection 4.3.2.

2.2. Cultural Dimensions

Many researchers, especially anthropologists, have explored various cultures worldwide and identified relevant aspects of each culture. Their findings derived dimensions that describe prominent characteristics to help classify and better understand a culture and its differences. A cultural dimension is “an aspect of a culture that can be measured relative to other cultures.” [90, p. 10] This chapter discusses various concepts of cultural dimensions and explains which will be essential to this thesis.

Hofstede’s Cultural Dimensions One of the most prominent concepts for analyzing cultural differences is the six dimensions of Hofstede [87, 89, 90]:

- **Power Distance (PD):** This dimension focuses on handling community power inequality. Low-power distance nations strive for evenly and fairly distributed power, while high-power nations value a clear hierarchy in their society.
- **Individualism vs. Collectivism (IDV):** The question in this dimension is to what extent an individual is integrated into groups, whereas individualistic cultures focus primarily on themselves and collectivist cultures focus mainly on the well-being of their group.

- **Masculinity vs. Femininity (MAS):** A low value in this dimension represents consensus orientation, caring for others, and quality of life; a high value symbolizes competitive achievement and a success-oriented society.
- **Uncertainty Avoidance (UA):** This dimension is about handling insecurities, the extent to which a culture feels endangered by uncertain, ambiguous, or unknown situations, and how strongly they attempt to avoid them.
- **Long-Term Orientation vs. Short-Term Orientation (LTO):** Short-term oriented cultures (low values) are normative societies that focus on traditions and norms and look at societal change cautiously; long-term oriented ones foster education and societal development to prepare for the future.
- **Indulgence vs. Restraint (IND):** This dimension describes the extent of controlling desires and impulses; restrained values (low) represent relatively strong, and indulgent values (high) relatively weak control.

Hofstede's main study, carried out between 1978 and 1983, analyzed the behavior of IBM employees worldwide, which resulted in identifying the first four dimensions [87, p. 41]: PD, IDV, MAS, UA. The study's objective was to identify aspects that impacted the attitude and values of the employees by conducting two survey iterations, which resulted in a total of 116,000 completed questionnaires from 72 countries in 20 languages. In 1987, the fifth dimension, LTO, was added to Hofstede's concept [89], derived in cooperation with Micheal Harris Bond, who conducted a "Chinese Value Survey" [231] and encountered this new characteristic. Finally, the last cultural dimension IND was discovered in 2010 together with Michel Minkov [90], who conducted a "World Value Survey". After Geert Hofstede's passing in 2020, the Finnish organization "The Culture Factor"¹ continues bridging academic research and public understanding of cultural differences in various contexts by translating new insights into accessible formats. The organization also ensures that the cultural dimension values remain current and reflective of contemporary research findings.

Hall's Cultural Dimensions Another anthropologist is Edward T. Hall, who has identified three cultural dimensions [71, 72] for describing cultural differences, which are:

- **Context (high vs. low):** Aspects of high-context cultures are that they do not say things directly and they do not report in detail, as this could be seen as negative. Further, much is taken for granted, confusing foreigners who do not know the unwritten rules. In contrast, low-context cultures tend to talk openly and do not assume people may know facts. Consequently, they provide many details and try to be precise.
- **Time (monochronic vs. polychronic):** The dimension of time correlates to context. Cultures that follow monochronic time do one thing at a time, schedule and plan carefully,

¹ <https://www.theculturefactor.com/>

and tend to be low-context cultures. Cultures with a polychronic time value human interaction over time and material things. They are more spontaneous, have fewer concerns about "getting things done," and tend to do many things simultaneously.

- **Space or Proxemic:** The third dimension, "space" or "proxemic", can either be high or low territoriality. High territoriality cultures are more concerned about security and ownership and set clear boundaries. They tend to be low-context cultures as well. Compared, cultures with low territoriality are less concerned with ownership and boundaries. They willingly share their territory and property and have fewer concerns about material ownership. They tend to be high-context cultures.

Trompenaar's Cultural Dimensions Fons Trompenaars and Charles Hampden-Turner have defined seven cultural dimensions [233], which can be summarized as follows:

- **Universalism vs. Particularism:** While universalism focuses on broad and general rules, particularism searches for exceptions to judge on their merits instead of adapting an existing rule.
- **Analyzing vs. Integrating:** Some cultures focus more on the details of life, which means they are "analyzing". Others focus on the big picture and bring things together.
- **Individualism vs. Communitarianism:** In individualistic cultures, the right is focused on the individual. In comparison, in communitarianism, the focus is on the rights of groups or society.
- **Inner-directed vs. Outer-directed:** This dimension describes where we find our information and make decisions based on our mind and intuition (inner-directed) or the information of the outer world (outer-directed).
- **Time as sequence vs. Time as synchronization:** Do people prefer to follow a sequence when performing activities, or do they try to perform them in parallel?
- **Achieved status vs. Ascribed status:** In cultures with an "achieved status", people expect to receive this status with high performance. In cultures with an "ascribed status," rules describe who earns this status, e.g., seniority.
- **Equality vs. Hierarchy:** This dimension is about whether a culture focuses more on equal status among them or expects societal hierarchies.

Victor's LESCANT model The LESCANT model by Victor [235] describes cultural aspects for the following fields:

- **Language:** cultural differences due to language differences
- **Environment:** physical surroundings, e.g. climate, food, topography, population density

- **Social Organization:** the structure of society, including family, education, the role of women, class systems, individualism, and religion.
- **Context:** direct communication of ideas and thoughts or context-related communication
- **Authority:** the role of authorities and the way power is executed and decisions are made
- **Non-Verbal:** other natural senses like vision, hearing, smell, taste, and touch
- **Time:** the management of people's time

Comparison and Cultural Dimensions Selection For the objective of this work, it is essential to describe cultural differences in UI design and preferences. Hence, a cultural model of the above described needs to be selected to enable a structured approach. Reviewing the cultural dimensions of these researchers, many similarities can be identified. Nevertheless, this work will focus on Hofstede's cultural dimensions because they are based on national cultures, with an up-to-date database of cultural dimension values for many countries. However, it must be considered that Hofstede's cultural dimension are strongly criticized [46] due to the methodological perspective of "stereotyping," and the use of nationalities as boundaries to cultures, etc. Nevertheless, approaches such as the one of Reinecke [186] overcome this issue by considering various factors that shape the user's cultural background: stays abroad, nationality of parents, etc. Moreover, her work applied this model to create an adaptive UI for a web application, which is an excellent example of how these dimensions can be used for such a personalization. To further underpin the suitability of Hofstede's cultural dimension, it is still widely used in academia, particularly in research on information systems and their design investigating cultural differences [65, 214], e.g., also in the field of intercultural or cross-cultural HCI and usability, e.g., [137, 187, 214, 239]. The characteristics of the dimensions can be analyzed to identify how they impact the UI design. All current values for the cultural dimensions relevant to this thesis are provided in Appendix A. As an example of the cultural dimensions, the indices for Germany are discussed to enable a better understanding of them:

- **PD:** Germany has a value of 35 in this dimension, indicating a low PD culture. Equality, collaboration, and direct communication are essential in work and private life, while control from above is not appreciated.
- **IDV:** Germany, as an individualistic culture with a score of 67, has citizens who are focused more on themselves and their direct family (parents-child relationships rather than uncles and aunts).
- **MAS:** Germany, with a score of 66, is a masculine society as achievements are highly important. Already in school, children at the age of ten are separated into different school types. When working, people derive their self-esteem from their work tasks; they are expected to be resolute and persistent and flaunt their status through material things (e.g., cars, watches, and technical devices).

- **UA:** With an index of 65, Germany is a high UA country. People strongly prefer deductive methods for thinking, presenting, and planning.
- **LTO:** Germany is a long-term-oriented culture with a score of 83. Distinct signals for this value are its pragmatic orientation, belief in the truth depending on situation, context, and time, and fast adaptation of traditions to new conditions. Moreover, Germans are persistent in achieving results and tend to save and invest their money.
- **IND:** Germany is a restrained culture with a score of 40. This means that Germans tend to be pessimistic and cynical. Moreover, they do not value leisure time or gratification of their cravings. Social norms restrain actions, and evidently, they feel uncomfortable when indulging.

3. Related Work

This chapter summarizes related work on how culture impacts usability and UX. Therefore, it investigates examples of applications where differences regarding cultural design preferences and culture have been observed to impact usability and UX. Further, it provides an overview of existing research findings on coping with different design preferences, mainly within marketing research and group recommender systems, and provides an overview of personalization approaches.

3.1. Cultural Impact on User Interfaces

This part gathers related work and findings concerning cultural differences in UI design. It includes studies that observed usability and UX issues due to cultural differences and improved usability or UX by considering them. Additionally, examples of Hofstede's cultural dimensions being applied to enable a more culturally aware UI are included. The findings are categorized into desktop (web) applications, mobile applications, and others. Finally, the identified cultural differences in UI design according to existing literature are summarized.

3.1.1. Usability and User Experience

This section presents several applications where cultural differences have impacted usability and UX. It mainly includes single-user applications, which shows that multi-user applications are not yet the focus of this discussion.

Desktop (Web) Applications

As a first example, an overview of intercultural usability is provided in [15], describing degrees of cultural awareness reported in [183] and showing examples of various website designs, focusing on the different forms of architecture, coloring, navigation, and graphics. Recommendations for color selection were already being discussed in 1998, as reported in [13], where a color-culture chart describes the colors' meaning in various cultures. For example, red symbolizes happiness in China, anger or danger in Japan, death in Egypt, aristocracy in France, and danger or stop in the United States. Further, a process for identifying cultural markers on websites has been proposed in [13]. Those markers are website elements that are highly frequent in one cultural group while absent in others. Moreover, the authors state: "No longer can issues of culture and usability remain separate in design for the World Wide Web" [13]. This emphasizes that culture was already identified as an essential usability factor long ago.

Also, based on websites, a study by [202] analyzes how cross-cultural systems embody indirect intercultural encounters. Therefore, they analyzed website designs by applying cultural viewpoint metaphors [44] and matching them with classes of signs [179]. They conclude that depending on the degree (Peirce's topology of signs [179]), signs can help users to get closer to other cultures or even enable an intercultural experience.

A study of various application types, but focusing mainly on desktop applications (e.g., word processing, spreadsheet, video conferencing, games, online banking, etc.), was reported in [203]. The aim was to identify whether cultural background influences the UX aspects of these product types. Therefore, they compared multiple study outcomes from Germany and Indonesia and concluded that there is a significant difference in the rating of UX aspects and that culture has a lower impact than individual differences. Further, it also showed that although many types of desktop applications were analyzed, the type strongly influences the UX.

Moreover, a study [30] focused on whether Hofstede's cultural models can help create a more culturally aware UI design for search engines. The study results showed a mixed review, as only three of the six cultural dimensions match the assumed user preferences, underpinning different preferences based on cultural background within them. This example shows that in some cases, not all cultural dimensions are relevant to impact the UX. Another exemplary study for applying Hofstede's cultural dimensions to improve websites has been reported in [63], where cultural differences in website design between American and Chinese students have been identified, which validates previous assumptions of cultural design preferences represented by Hofstede's cultural dimensions. A comparative content analysis of websites from various countries [22] revealed differences in graphical UI design based on cultural dimensions, including UA and PD. This study emphasizes the influence of culture on web design and the need for culturally sensitive interfaces. Also, it was identified in [215] that cultural differences require cross-cultural design attention, such as language, format conventions, and text directionality. As highlighted in [62], applying cultural dimension theories to identify website design preferences across different cultures is vital. Additionally, the importance of internationalization and localization strategies in cultural usability studies for developing interfaces appropriate for users from particular cultural backgrounds has been emphasized in [12]. In a broad analysis of websites and cultural differences [5], 460 examples were analyzed by identifying cultural differences concerning seven design attributes. Another study [4] investigated the effect of a culture-adapted website on usability by comparing versions that considered Australian and Chinese design preferences using Hofstede's cultural dimensions, among others. They identified that considering culture positively impacted usability, further underpinning and proving that it is an ongoing research topic. A vital study that underpins the relevance of culturally sensitive UI is presented by the work of Reinecke [186, 187, 188], where a website for task management is adapted according to the user's cultural background, determining a significant positive effect on usability [187].

Another approach documented in [122] focuses on embedding culturally sensitive steps into standard development processes for new UI. In detail, the study compared design preferences between two nationalities, Germany and Vietnam, and applied the Hofstede model to identify differences in UI design for deriving a more suitable culture-specific web application, a Q&A

website. The authors conclude that the UI differences derived from Hofstede's cultural dimensions were helpful for the design process, as they increased awareness about the differences that need to be considered when designing cross-cultural products.

Within the research field of learning management systems, several studies incorporated cultural differences in the design of online teaching material, summarized by [10]. This field targets, for example, the design of massive open online courses [230]. This study identified that it is vital for teachers or lecturers to be aware of the cultural diversity among students and how that impacts the usability of the provided learning material. This example further emphasizes that designers of such material and UI should consider the cultural impact on the users' perception. Improving groupware applications to cultural preferences was the subject of interest reported in [228]. They motivate and present ideas on how cultural adaptation can impact the usability of groupware applications. Similarly, an approach to tailor groupware to various cultural preferences for groups is discussed in [95]. However, they briefly introduce how the group derives a shared UI design using manual customization, missing details about merging different cultural preferences, as it is not necessarily based on a strategic adaptive approach.

Mobile Applications

Regarding cultural differences in the UX of smartphones, a study [239] conducted an evaluation using the remote online sentence completion method and identified differences in usability, context and meaning, aesthetic aspects, subjective feelings, and identification. According to [240], considering cultural aspects in mobile health applications (mHealth) can affect the UX. Another approach concerning mobile applications is reported in [7], revealing that tailoring mHealth interface designs to cultural preferences resulted in high user satisfaction among Arab users. This emphasizes the benefit of considering cultural factors in UI design for an enhanced UX. They suggest culturally adaptive interfaces to ensure usability and effectiveness across different cultural contexts.

Other Applications and Devices

An interesting intercultural evaluation was reported in [174]. Within this study, Google standardized symbols were evaluated for a bakery dough sheeter. The researchers of this study followed an interesting viewpoint as they assessed the symbols for handling the dough sheeter with a group of people, potentially with the same cultural background, as no further information was provided, arguing that the worldwide high usage of Google signifies that Google symbols are intercultural. The evaluation concludes that over 20 % of Google icons showed a high degree of icon-to-function assignment. They plan to conduct evaluations with an intercultural test group to validate their results and for further insights. Another example evaluates the usability of grid computing applications, which share various types of computational resources in different locations and, consequently, are an intercultural challenge, [199] proposes a set of heuristics for evaluation purposes but does not focus on the UI design.

Within the field of automotive design, several studies [77, 81] describe the development of an intercultural automotive UI/UX design using agile methods. This research uses culture-specific requirements and international design decisions to design culture-specific interactions in an automotive context. The authors argue that intercultural aspects must be part of the design development process, but focus on designing for a particular culture and understanding differences rather than merging them. Another study analyzing the UI design in an automotive use case is presented in [103]. In this study, Hofstede's cultural dimensions were used to identify differences between the UK and India and thus change the UI for the respective user. The corresponding personalized UI versions were perceived to match the user's preferences better, emphasizing the positive impact of such culturally aware solutions on usability.

An analysis where researchers investigated how and whether cultural differences are considered in technology design is discussed in [246], focusing on product development. In this paper, the authors discuss use cases where the development team improved a website and an intelligent personal assistant (desktop) and how or when they applied research findings, such as research that considers Hofstede's cultural dimensions and derived differences for UI design. They identified that developers rely on their own experience and local experts in practice rather than using existing knowledge from research, as it was unfamiliar to them. This example highlights the lack of transfer from academia to industry, in particular, as industry would profit from accessible and border-crossing exchanges.

A generic approach to consider cultural differences in the design process is presented by [79]. On a high level, the author proposes how these differences can be incorporated into the human-centered design process without focusing on one specific application or device. However, this work focuses on improving the UI for a particular user or culture, not necessarily for a group.

3.1.2. Differences in User Interface Design

While understanding cultural differences is already an outstanding achievement, it is interesting how they can be systematically applied to UI design. For this purpose, it would be interesting to identify UI aspects and how they differ depending on the degree of Hofstede's cultural dimensions. With this knowledge, UI adaptations tailored to specific cultural dimensions' values can be implemented. One existing, widely used classification is the UI elements by Marcus [138]:

- **Metaphors:** fundamental concepts explained to users via words, images, sounds, and tactile experiences to support users in remembering and enjoying the interaction.
- **Mental models:** the navigation and structure of data, functions, tasks, roles, and groups, also called user, cognitive, and task models.
- **Navigation:** concerns the transitions through mental models using content and tools.
- **Interaction:** input or output possibilities and feedback to the user.
- **Appearance:** all UI aspects the user perceives visually, auditory, or tactile.

However, these UI elements summarize various design preferences when analyzing the mapping to Hofstede's cultural dimension [138]. Consequently, to determine another more granular list of UI aspects and their cultural differences mapped to the cultural dimensions, various studies about cultural differences in UI design, e.g., [135, 140, 187], can be analyzed. Using this existing literature, 15 UI aspects can be identified as culturally relevant, summarized in Table 3.1. These represent the potential UI changes and preferences for personalizing UI mapped to Hofstede's cultural dimensions and their sources, where these preferences have been determined.

Table 3.1.: Derivation of culturally relevant UI aspects based on cultural dimension (CD), their low and high adaptation, including sources.

CD	Low	High	Sources	UI Aspect
PD	non-linear navigation, high access to functionalities	linear navigation, few links, minimized navigation possibilities	[22, 88, 140, 236]	navigation, access to functionalities
PD	unstructured data	structured data	[136, 140]	content structure
PD	many functionalities	reduced choices of functionalities	[88]	access to functionalities
PD	low hierarchy, showing many content details at first sight	strong hierarchy, showing not many content details at first sight	[22, 140]	level of detail
PD	error messages are friendly and suggest further steps	strict error messages	[88, 140, 141]	feedback and error messages
PD	rare support	strong support	[140]	support, assistance, hints
PD	pictures show leaders or organization	pictures show people in daily activities	[67, 140]	content type
IDV	traditional colors and pictures	colors used to encode information	[140]	informativeness (of colors and pictures)
IDV	high picture-to-text ratio	high text-to-picture ratio	[67]	picture-text-ratio
IDV	high multimodality	low multimodality	[83]	multimodality
IDV	colorful interface	monotonously colored interface	[13]	colorfulness
IDV	formal content, community or product-related	formal content, focusing on individuals	[140]	content type
MAS	low saturation (pastel)	high saturation (bright, high contrast)	[47, 236]	color saturation

Continued on next page

CD	Low	High	Sources	UI Aspect
MAS	explore various navigational paths	restrict navigational paths	[1]	navigation
MAS	personal and kind communication	encouraging communication	[26, 47, 88]	feedback
UA	most content details are already at first interface level (complex)	low details at first interface level, strong hierarchy	[22, 29, 31, 86, 135, 140, 141, 249]	level of detail
UA	non-linear navigation	linear navigation, display the user's position	[22, 36, 88, 100, 135, 139, 140, 141]	navigation
UA	encode colors, typography, sounds with information	increase coding with redundant color use	[140, 141]	informativeness (of colors, typography, sounds)
LTO	low content density	high content density	[139, 140]	content density
LTO	highly structured content in little blocks	arrangeable content around a focus point	[140]	content structure
IND	formal content, work and community-related	informal, humorous content generated by users	[14, 90, 162, 163]	content type
IND	strict gender roles where applicable	loose gender roles	[162, 163]	gender roles
IND	formal, explainable, interaction	gamification, fun interaction	[162, 163]	joy of use
IND	highly structured content	low structured content	[162, 163]	content structure

3.2. Handling Diverse (Design) Preferences

This section discusses how diverse preferences have been handled and considered in other disciplines and related fields, which can concern UI design and different aspects. In the beginning, related work regarding software internationalization and international UI is discussed. Moreover, research within the field of Marketing is summarized with a focus on considering cultural differences. Additionally, current research examples within group recommender systems and where they are applied are presented in detail to identify whether there are interesting insights that can be helpful for intercultural personalization and merging diverse design preferences. This summary provides an overview of existing findings on achieving a result or recommendation suitable for multiple people. This may help differentiate this thesis from existing work and gather supportive information for further refinement.

3.2.1. International Interface Design

When targeting the personalization of a UI to an intercultural group, the following central terms may be related: Internationalization, localization, and globalization of software UI. The relevance of these terms is discussed to deepen the understanding of this work and its scope.

Concerning software development, localization is defined by Schmitz [205] as “[...] the whole process of adapting a software product to a local or regional market with the main goal being the consideration of all appropriate linguistic and cultural aspects.” It is about improving the software UI by considering local preferences. The term internationalization is closely related to localization, as it is about the development steps for software so that it can easily be adapted to local preferences at a later stage [49, 189, 205, 206]. Hence, it should enable localization by reducing or removing the need to rethink the general software architecture when it has already been adapted to a particular location [205]. Consequently, the objective is to move as many activities and aspects towards being internationalized and reduce as many aspects of the software to be localized, as it reduces costs and effort [205]. According to [96], the following aspects need to be considered as early as possible within the internationalization steps before localization, as they need to be adapted during the localization phase:

1. A universal code base
2. Text direction
3. Names, addresses, and such
4. Time zones, currencies, dates, etc.
5. Cultural norms and expectations

Considering these aspects beforehand, their localization is way easier and cost-efficient [96, 205]. Globalization originates from marketing and refers to the overall objective of promoting a product outside a national market, considering diverse national conditions technically, economically, and legally [204, 206]. The perspective of globalization and its relation to this thesis will be discussed in detail in the next section.

While the approaches presented in this part cover interesting ideas on how an international UI design can be achieved, which is applied to diverse user groups, the result often focuses on compromising design, which is not necessarily tailored to the users but tries to be acceptable for many, or still considering design differences but tailoring it to a specific locality, not trying to merge preferences. This differs from the objective of this work, which is about how to personalize the UI based on a group's preferences, involving the derivation of a solution by finding a compromise.

3.2.2. Intercultural Marketing

When considering similar findings in marketing research, terms include globalization, internationalization, adaptation, standardization, and intercultural marketing. The general principle for successful marketing strategies is to adapt products to the local markets the brand is targeting

[163, p. 12]. Such strategies lead to mantras like “Think globally, act locally” [195]. This example already shows that the overall objective is not to merge differences but to focus on one specific characteristic of users that the brand or product is targeting and then personalize the marketing strategies towards this characteristic.

Related work in the research field of intercultural marketing classifies approaches for successful strategies from a more general perspective according to [234, p. 228]:

- Standardization-adaptation of market offerings
- Geographical concentration dispersion
- Integration-independence [128]

The first type of classification for such strategies focuses on standardization, which is described as a strategy that “views global marketing strategy as being the same or standardized across countries, including all elements of the marketing mix, product, promotion, price, and distribution strategies. There is general acknowledgment that there are some environmental constraints, owing to the physical conditions within a country, as well as legal issues, especially product standards, taxes, etc. Consumer needs in various national markets are not strongly considered, as differences are denied or treated as an external constraint. Behind the globalization debate, there is a quite practical issue in terms of the everyday life of companies: the traditional dilemma between production flexibility and the (marketing) tendency to customize products to diversified needs.” [234, p. 228] Another finding that further underpins this perspective is determined in [97], which evaluated academic contributions on standardization within this field over the last 40 years and derives the following key insights:

- End-to-end standardization is not conceivable.
- Deciding on standardization is not binary; it is more about the degree of standardization.
- Product/industry characteristics are decisive over the total variety of internal and external factors influencing the decision on standardization.
- Well-developed marketing infrastructure enables standardization.

Looking into the product attributes from a marketing perspective that were mainly standardized across cultures, research reported in [238] investigated the marketing standardization and adaptation of 500 large UK companies operating in multiple nations. Concerning the standardization percentage, mainly abstract aspects (product quality (78%), brand name (72%), image (71%), and performance (67%)) were targeted in the companies. In the middle field, the standardization partially focused on the product design (size and color (54%), packaging and styling (52%), variety, design, and features (48%)), and least often concerning services (pre-sales service (45%), after-sales (43%), delivery and installation (42%)), which is probably due to substantial local differences. Interestingly, the number one reason for adaptation was reported to be culture, with 92%, underpinning the importance of this factor in overall marketing objectives.

Investigating advertisement as a sub-area of marketing, the following factors help decide which aspect of the ad can be standardized [74]: product factors, competition, organization variables, media infrastructure, regulations, and market/societal variables. Also, “given the strong economic and administrative rationale it is assumed that, if possible, advertisers would prefer to standardize advertising” [74, p. 58]. Additionally, it was determined that not all advertising elements are suitable for standardization [154]. This study further explains their result by pointing out that the overall advertising theme can be standardized but must be customized for local or targeted execution. These statements show that globalization does not necessarily involve merging different preferences in intercultural marketing. Instead, it is about denying them and identifying what aspects of the marketing strategy can be standardized to reduce costs [158]. The interplay between standardization and customization is also discussed in [59], which reports that the success of standardization depends on the product’s cultural ties, the similarity of purchasing behavior, the competition, and laws and regulations [118]. However, evaluations of various marketing campaigns conclude that global strategies might sound attractive to reduce costs but can even ruin the brand’s image in the long term, while culture-specific campaigns are more successful and positively impact the brand’s success [59]. Moreover, this point of view is also determined by Mooij [158, p. 61], who investigates global branding of products and reports that “effective advertising reflects the values of the audiences it targets.”

Interestingly, Hofstede’s cultural dimension has also been widely used in marketing efforts. The joint work of Geert Hofstede and marketing researcher Marieke de Mooij reflected how these two research fields intervene and how the Hofstede model can be applied to support cross-cultural branding and advertising [157, 159, 160].

Comparing all these findings from the Marketing field, the consideration of cultural differences is investigated from a high-level point of view: It is more about the overall development of products and how to sell them. This affects the production of products to sell and the distribution, etc. However, it does not necessarily describe how to merge different preferences but instead discusses in which respect ignoring them might profit and not hurt the overall success of a company. In addition, no strategic approaches for merging different design preferences were presented, only for adapting to a specific preference or characteristic of the target users. Additionally, the personalization focus differs from the one for interactive devices as it does not focus on improving the UX and supporting a particular topic, such as knowledge exchange in semi-public areas, but focuses more on how to design products, sell them, and how these kinds of marketing strategies can be adapted to local groups.

3.2.3. Adaptive Systems

Several examples presented in the previous sections highlight the need for systems and their UI to be tailored to users. In this context, the concept of adaptive systems often appears and is particularly relevant for this work’s objective of personalizing a system’s UI for a group with diverse preferences. As defined in the previous chapter, adaptivity is a personalization in which the system changes itself without user involvement [172]. Consequently, this section summarizes what is vital for developing adaptive systems.

As adaptive systems are also a widely investigated research field, another definition by Benyon and Murray [17] further defines it as “systems which can automatically alter aspects of their functionalities and/or interface in order to accommodate the differing needs of individuals or groups of users and the changing user needs over time.” They additionally propose an architecture that contains all relevant elements for such an adaptive system, which are:

- **User Model:** The user model represents the knowledge and preferences of a user (individual or group), which is assumed by the system.
- **Domain Model:** The domain model describes the application parts to be tailored by the system.
- **Interaction Model:** The interaction model represents the connection between the user and domain model (application) and how this interaction is designed. This interaction is hereby limited to those that the system can monitor.

For the development of an adaptive system, the following steps are required [17]:

1. Identify: Need for adaptivity, which features should be adaptive, variety of users, and environment within the adaptive system is used
2. Decide on the scope of adaptivity and how to measure it
3. Consider data collection for user model: explicit or implicit
4. Identify what data can be collected through interaction
5. Evaluate and improve the adaptive system

This overview of adaptive systems, including basic requirements and a potential development process, is beneficial as it provides information on what to consider when personalizing the UI design for a group, focusing on adaptation. One essential aspect for such adaptive systems is the user model. As this work targets merging diverse preferences, it is necessary to derive a group model to decide how the UI can be personalized. Group modeling is a vital part of group recommender systems and is discussed in the next section.

3.2.4. Group Recommender Systems

This section summarizes relevant information about the development of group recommender systems. Therefore, several approaches are presented and discussed. These development steps provide essential parts for personalizing the UI of large interactive displays for intercultural groups by considering group modeling characteristics.

Within group recommender systems, groups and their diverse preferences are investigated. Group preferences are described as either homogenous, when preferences are similar, or heterogeneous, when they are not similar [41]. Besides this distinction, the following types of groups can be distinguished according to [20]:

1. **Established Group:** A group of people who explicitly choose to be a part of the group based on long-term, shared interests.
2. **Occasional Group:** A group of people who perform some activity occasionally together. All the group members will have a common aim at a particular moment, e.g., museum guests.
3. **Random Group:** A group of people who share an environment at a particular time without any task or objective that connects them, e.g., public areas.
4. **Automatically Detected Group:** Groups derived by technology based on the user's preferences.

Another important step that shapes group recommender systems is strategies for generating group profiles. Hereby, the strategies commonly distinguish between [20, 27, 99]:

- **Aggregating Preferences** of the users (usually these are ratings for items) to generate a group profile and derive recommendations based on this group profile.
- **Aggregating Recommendations** identified for each user, before being aggregated into a group recommendation.

The choice of aggregating profiles (preferences) or recommendations can vary and be combined [146]. However, aggregating profiles is recommended if possible [27].

Another approach presented in [99] identifies the following four subtasks as vital for group recommender systems:

1. **Acquiring information about user's preferences:** This process step distinguishes two types: explicit vs. implicit gathering of preferences. Explicit preferences are gathered, for instance, through surveys, user testing, and actual ratings of items. Implicit preferences can be derived by monitoring user behavior, e.g., analyzing interaction data or using other socio-demographic data such as gender, age, and cultural background.
2. **Generating recommendations:** Before deriving group recommendations using common strategies such as collaborative filtering, content-based, constraint-based, etc., this step aggregates the user's preferences within a group.
3. **Presenting recommendations to the group:** Is it a final single recommendation or a list? Is it negotiable or fixed? Additionally, explain how the recommendations were derived.
4. **Helping users to find consensus**

While these tasks cover relevant aspects of group recommender systems on a high level, the step of group modeling can further be investigated in more depth, as it targets the aggregation of individual preferences. Concerning this task, Masthoff [144, 145, 146] propose the following dimensions to classify group recommender systems based on their group modeling approach, which is interesting to understand its impact on the overall group recommender system:

- **Individual preferences are known vs. developed over time:** In most cases, they are known initially for individual users. However, it can be distinguished whether, for example, the group preferences develop over time or individual preferences change during group discussion.
- **Experience of the recommendation or receive a list with options:** Some recommenders deliver a list of recommendations from which the group can choose; in others, the group only consumes the recommendation without selecting a specific one.
- **Active vs. passive group:** Passive groups do not influence the group model generation, and active groups negotiate it, which is also reported in [27].
- **Negotiation vs. single recommendation:** This dimension distinguishes whether the group can negotiate the recommendation several times or if it is a “single-shot” recommendation.
- **Recommending a single item vs. a sequence of items:** It can impact a group recommender system’s success if only one item or a sequence of items is recommended. With a sequence, potentially several preferences can be intercepted, while with only one item, all group members must agree or be satisfied.

As the group modeling part of the group recommender systems development is most interesting for this thesis, the eleven common strategies are presented in the next part.

Table 3.2.: Overview of aggregation strategies [146].

Strategy	How It Works
Plurality Voting	Uses “first past the post”: repetitively, the item with the most votes is chosen.
Average	Averages individual ratings.
Multiplicative	Multiplies individual ratings.
Borda Count	Counts points from items’ rankings in the individuals’ preference lists, with the bottom item getting 0 points, the next one up getting one point, etc.
Copeland Rule	Counts how often an item beats other items (using majority vote) minus how often it loses.
Approval Voting	Counts the individuals with ratings for the item above an approval threshold (e.g. 6).
Least Misery	Takes the minimum of individual ratings.
Most Pleasure	Takes the maximum of individual ratings.
Average without Misery	Averages individual ratings, after excluding items with individual ratings below a certain threshold (say 4).
Fairness	Items are ranked as if individuals are choosing them in turn.
Most Respected Person	Uses the rating of the most respected individual.

Group Modeling Strategies

The approach to derive a group model by aggregating ratings or preferences uses strategies originating from the Social Choice Theory (group decision-making) (for an in-depth discussion, see [143, 180]), commonly applied in other disciplines, e.g., economics or politics. The overview in Table 3.2 introduces several possible strategies, which are further evaluated, whether and how they can be applied to this work for merging cultural design preferences. Applying these strategies to cultural dimension values and considering their unique characteristics has also been discussed in [222]. To better understand where such strategies are applied, the next part summarizes examples of group recommender systems and their group modeling strategy used, if known.

Application Examples of Group Recommender Systems

Examples of applications where group recommender systems have been deployed are helpful to get a better understanding of current use cases. As the focus in this work is more targeted on the group modeling, the previously introduced classification of the systems [144, 145, 146] is applied to the examples and provides an overview of which strategies are used in which use cases, in Table 3.3.

Additionally, the potential of aggregation strategies was evaluated in prior research to identify which strategy performs best. It was determined that the strategy “average” worked well for homogeneous groups [248], which is reflected as “the Average Strategy will make individuals quite happy if they are quite similar, but will cause misery when tastes differ widely” [146]. A more extensive evaluation of group modeling strategies was reported in [143], which derived that users cared about fairness and preventing misery and starvation, which can also be found in several aggregation strategies, e.g., average, least misery, average without misery, fairness. Moreover, it was identified that concerning satisfaction, the multiplicative result was rated as best, followed by Borda count, average, average without misery, and most pleasure [143]. Strategies that resulted in misery for a group member were, for example, Copeland rule, plurality voting, and least misery.

The overview in this section (Table 3.3) displays current applications for aggregating group preferences and indicates which group modeling characteristics and strategies were used. It provides a basis for better classifying and deciding which approaches are most suitable for aggregating cultural user profiles and deriving recommendations for a personalized UI design based on the group’s design preferences. Overall, Subsection 4.3.2 discusses which aspects of group recommender systems and other findings of the related work are relevant and applicable to this work.

Table 3.3.: Examples of group recommender systems based on classification and strategy used [146]. Abbreviations: P = Preferences Known, D = Direct Experience, A = Group Active in Decision, S = Sequence or Multiple Items, Strategy = Strategy Used for Group Modeling.

System	Usage Scenario	Classification				Strategy	
		P	D	A	S		
MusicFX [150]	Chooses radio station in fitness center based on people working out	Yes	Yes	No	No	Average	without misery
PolyLens [170]	Proposes movies for a group to view	Yes	No	No	No	Least misery	
Intrigue [9]	Suggests tourist attractions for subgroups	Yes	No	No	Yes	Average	
Travel Decision Forum [98]	Supports agreement on vacation attributes	Yes	No	Yes	No	Median	
Yu's TV Recommender [248]	Recommends TV shows based on ratings	Yes	No	No	No	Average	
CATS [151]	Recommends joint holidays based on individual ratings	No	No	Yes	No	Without misery	
Masthoff's Group Recommender [42]	Music video sequencing based on ratings	Yes	Yes	No	Yes	Multiplicative, etc.	
GAIN [42]	Displays group-adapted info and ads	Yes	Yes	No	Yes	Average	
REMPAD [18]	Multimedia for reminiscence therapy	Yes	No	No	No	Least misery	
HAPPYMOVIE [184]	Movie recommendation for groups	Yes	No	No	No	Average	
INTELLIREQ [52]	Group requirement decision support	No	No	Yes	Yes	Plurality voting	
Where2Eat [70]	Group restaurant recommender with negotiation	No	No	Yes	No	Counter proposals	
CHOICLA [218]	Domain-independent group decision tool	No	No	Yes	No	User-selected strategy	
HOOTLE [142]	Negotiates hotel features and preferences	No	No	Yes	No	Borda Count variant	
STSGroup [167, 168]	Chat-based POI recommender	Yes	No	Yes	No	Weighted average	
TOURREC [84]	Suggests personalized routes via POIs	Yes	No	No	Yes	Connect segments (CS)	

Part II.

Design and Development

4. Requirements Analysis

Effective personalization of large interactive displays for intercultural groups in semi-public areas requires a structured understanding of key requirements. This chapter identifies and derives these requirements by analyzing the context of use, necessary group modeling strategies, and key UI aspects for personalization. The determined requirements (REQ) form the foundation for developing the personalization approach and verifying that all relevant aspects are considered.

First, the contextual use of large interactive displays is examined, including their location, typical interaction time, usage patterns, etc., as these factors impact design decisions and the degree of user involvement. Moreover, the degree of personalization is also analyzed to define precise requirements for the intercultural personalization approach.

Next, the requirements for successful group modeling are identified, specifically for merging cultural user profiles. This includes determining the necessary user information, which is fundamental to creating a cultural user model. Subsequently, aggregation strategies for these values are discussed. A comprehensive discussion of common group modeling strategies highlights their applicability in this context and identifies the most promising ones.

While previous research (Table 3.1) has summarized differences in cultural design preferences, it remains unclear whether all these aspects are relevant for large interactive displays as many were derived from web application studies. Therefore, this chapter identifies the key UI aspects critical for the intercultural personalization of large interactive displays.

In summary, this requirements analysis establishes the foundation for the personalization approach developed in this thesis, ensuring all relevant aspects are considered systematically in the design phase.

4.1. Context Analysis

This section discusses requirements from factors impacting intercultural personalization, which originate from the surroundings and the context of where the large interactive display is deployed and used. Such factors relevant to the context of large interactive displays and the objective to personalize the UI design have already been partially summarized in [221]. Overall, the questions to be answered in this section are: How much user involvement is required to achieve intercultural personalization, considering the usual interaction time with large interactive displays in semi-public areas and the necessary user identification to succeed in UI personalization? What are the potential degrees of personalization and an approach to capture all relevant personalization aspects?

4.1.1. User Involvement

A decision on the most suitable degree of user involvement is necessary for the personalization objective as many factors impact it. Relevant in this context are the typical interaction time, possible user identification, and the characteristics of the application that should be personalized. The possibilities of user involvement are presented before discussing these factors in more detail. Generally, Fan and Poole [50] and Oppermann et al. [172] describe various extents to which a user can be involved in the system design. These degrees are displayed in Figure 4.1. The two extremes that describe personalization approaches relevant to this work are adaptive and adaptable [172]. While these terms sound similar, their meaning differs: In adaptive systems, changes are initiated by the system without user control. In adaptable systems, users initiate the changes while the system does not change anything autonomously. Before deciding on the degree of user involvement, the relevant factors, user identification, interaction time, and other characteristics of large interactive displays are discussed.

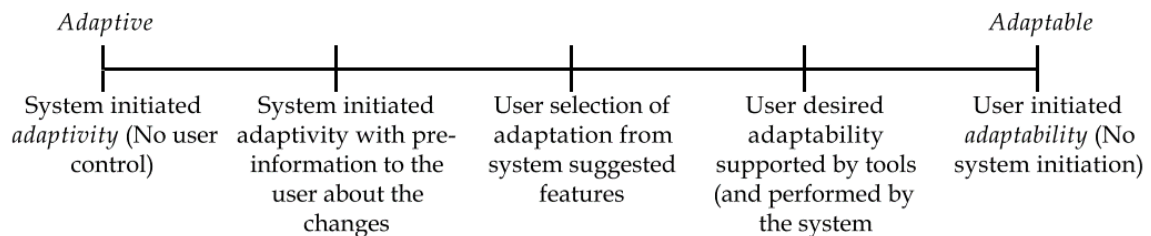


Figure 4.1.: Spectrum of adaptation in computer systems [172].

Characteristics of Large Interactive Displays

A summary of differences between desktop applications and wall displays is provided by Huang et al. [93]. The following part presents and discusses these differences to enable a comprehensive understanding of the contextual challenges that are vital for personalizing such displays:

- **Form factor:** The physical size enables different interactions, visibility, and multi-user interactions, e.g., content is viewable from a greater distance than desktop applications. This affects the users' perception and interaction with these displays.
- **Public audience and location:** They are usually located in a common area, leading to different types and amounts of attention. Interacting with these displays is more visible and less private.
- **Outside personal workspace:** Interactions with these displays differ because they are located outside their personal space. This impacts the user's willingness to explore and discover its usage.

- **Group owned:** These displays are perceived as a group resource, where users feel less responsibility and personal ownership of the device, its content, and its use. This impacts the usage of the application and the interaction style with content.

Based on the form factor, personalization must address the preferences of various users as the display should enable multi-user interactions. The location of these displays leads to more exposed interactions, which also impacts the user's involvement in design decisions: Does the user want to be observed when changing the UI, or should the UI already provide a personalized experience? Is the user willing to contribute to personalizing the UI design? Furthermore, the lack of responsibility for the large interactive display may also hamper users' willingness to contribute to its personalization as it is a group resource. It seems that it would be more convenient for users to consume the content others have provided or what the display selects itself than to contribute content or customize the UI themselves. The display is much more expected to provide relevant ambient information [116] proactively. These factors are relevant for selecting the degree of user involvement.

Interaction Duration

Another aspect relevant to the contextual use of such displays is the duration of interaction: the average interaction time of single- or multi-users is not supposed to exceed several hours or longer. As an example, some of these displays are used to increase awareness about current activities in the company and foster knowledge exchange. Also, their location is exposed and in areas where users pass by, usually without the specific goal of interacting with the screen but pursuing other activities, e.g., going for lunch or to another meeting. This usually leads to limited interaction time.

User Identification

To enable personalization, it is necessary to know the users and their preferences. This means that user identification is required. The locations of such displays relevant to this work are semi-public areas. Such areas are access-restricted and require user identification to some extent, e.g., access control to the site or the buildings and offices. Consequently, for the personalization approach, it is possible to know to a certain extent which persons are currently in that semi-public area or which ones are usually located there, e.g., as their offices are located in the surroundings of the display. Depending on the location, there are various identification possibilities: Some companies have already established a desk booking system for office spaces, which delivers relatively precise user identification. Following the open office philosophy, other companies still provide department-specific work areas, which would also allow user identification in that area as it is known which departments are assigned to which location. For more traditional offices, occupancy is known as employees are assigned to a specific space with little to no changes. This can be used for user identification. However, it is not only important to identify the particular persons with access to a certain area. For further personalization, it will also be required to

know the cultural background of these persons. All these personalization ideas require potential users to submit information about their cultural background. Based on this information, their cultural profile is calculated and can be used when the user is assigned to a location near one of such interactive displays. In contrast to this more indirect user identification, the real-time identification of users relies on personal devices, Bluetooth or RFID, biometric measurements, face recognition, or other sensors, which can be applied in ubiquitous computing. However, these data sources for user identification should be minimized [250] as they are strongly regulated by data privacy. They are not necessarily applicable for large interactive displays in such areas as they should still follow basic principles like Walk-up-and-use (based on Koch [110] or the definition for ubiquitous computing from Weiser [244]), which means that no additional device is required to interact with the display. As real-time user identification is not applicable, focusing on intercultural personalization is promising even with indirect user identification through analyzing the display's surroundings by standard office occupancy. Overall, the display is deployed in a semi-public area and must consider several design preferences of multiple users located nearby. Real-time user identification and ad-hoc personalization would enable a personalized UI version for that particular person. Still, they would not consider other users' preferences.

Reflecting on this discussion of the unique characteristics of large interactive displays, interaction duration, and user identification, the need for users to get involved in making design decisions should be kept to a minimum.

REQ1: Minimize user involvement: Adapt the UI to intercultural design preferences for a small group as independently as possible. Consider this constraint also during data acquisition.

4.1.2. Personalization Approach

Reflecting on the previous paragraphs, deciding on a personalization degree, an adaptive or adaptable system, the most suitable approach would be to derive an approach for an **inter-cultural adaptive** UI for large interactive displays in semi-public areas. It seems unrealistic that users initiate, discuss, and agree on a specific design, especially given the typically very short interaction time and low user commitment. Thus, the following work focuses on deriving a personalization approach that emphasizes adaptivity for large interactive displays.

Additionally, to the degree of user involvement, personalization potentials can further be distinguished into design paradigms that provide an overview of various perspectives on personalization for a more structured approach. Such design paradigms are defined by Fan and Poole [50] and can be used to derive personalization potentials systematically as they are divided into commercial, architectural, relational, and instrumental. To map these paradigms to this work's context, the previously identified 15 UI aspects (Table 3.1), which are culturally relevant as there were cultural differences in design preferences, are mapped to the four design paradigms as follows (see also Figure 4.2):

- **Commercial** (content of the system): content type
- **Architectural** (interface aspects, design and layout, form and function): navigation, structure, level of detail, picture-text-ratio, colorfulness, saturation, density
- **Relational** (meaning, fostering interactions between users): feedback and error messages, support, assistance, hints, informativeness of colors, gender roles
- **Instrumental** (functionality and usability of the system): access to functionalities, multimodality, joyfulness

As described in [221], a personalization approach considering various perspectives in this work's context would require adapting at least one UI aspect of each design paradigm. However, the UI aspects may not equally occur in applications for large interactive displays as they were derived from web applications. Subsequently, it is necessary to investigate systematically which are the most common. Thus, personalizing these UI aspects would be most interesting as most designers and users would benefit from them.

REQ2: Ensure a structured approach by selecting a UI aspect from each design paradigm to incorporate various perspectives on personalization.

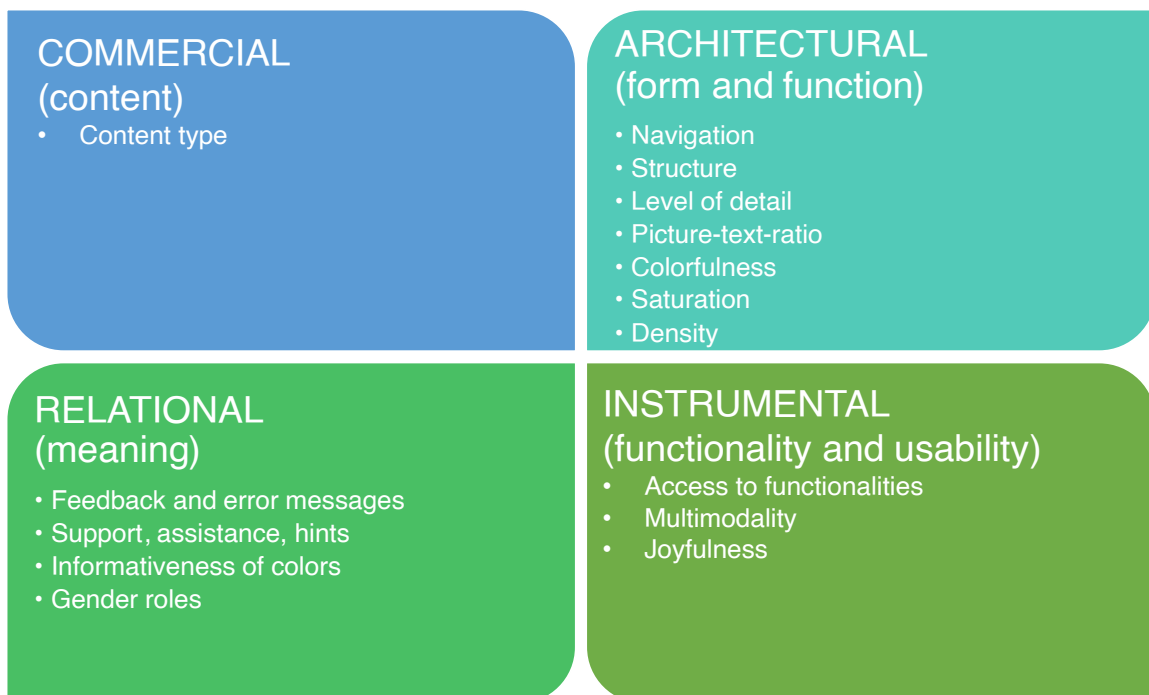


Figure 4.2.: Matching culturally relevant UI design aspects [221] to design paradigms [50].

4.2. Key User Interface Adaptations

As identified in Subsection 3.1.2, 15 UI aspects are culturally relevant for UI design. But, as they were mainly observed in single-user applications, they must be analyzed to identify which UI aspects are most vital for large interactive displays. Table 3.1 provides an overview of these UI aspects and their related design preferences in conjunction with Hofstede's cultural dimensions. Depending on the group's or the user's values in their respective cultural dimension, high or low, the corresponding design preference is assumed. This section identifies the key UI aspects for large interactive displays and the general adaptation rules. These rules represent a vital requirement for developing a culturally adaptive UI as they describe **what** should be adapted, **when**, and **how**.

4.2.1. Key User Interface Aspects

Because adapting 15 UI aspects is a challenging task, it is important to reduce this number and identify the key aspects that are most relevant for large interactive displays. In particular, not all derived culturally pertinent differences of UI design (Table 3.1) are applicable in large interactive displays as they originated from analyzing web applications. Consequently, the application of these findings to large interactive displays in semi-public areas draws new challenges and opportunities for multi-user interfaces, in contrast to single-user interfaces [219], especially as the UI of large interactive displays is an example of a "shared reality" [82], used by many.

To obtain insights relevant to many large interactive displays, the question remains whether all UI aspects pertinent to cultural web design adaptation equally apply to them. To investigate this further, various designs for large interactive displays were analyzed to identify the key UI aspects of this type of device. Research articles in relevant databases were systematically reviewed to gather and analyze the UI design of large interactive displays in more detail. To explain further, application examples of large interactive displays were evaluated regarding their design and whether the UI aspects are relevant or exist for the application. This procedure considers various application examples, providing a basis for a more concise list that classifies the culturally relevant UI aspects according to their appearance in most of these devices.

The Systematic Literature Review

A systematic literature review based on the process of Vom Brocke et al. [237] was conducted to identify application examples for large interactive displays and determine vital aspects of their design. The following steps [237] were taken, described in detail in the next paragraphs:

1. Definition of review scope
2. Conceptualization of the topic
3. Literature search
4. Literature analysis and synthesis
5. Research agenda

Definition of Review Scope

The scope of this review is defined to identify the key UI aspects of large interactive displays. The following keywords were used “large interactive displays,” “large display,” AND “interactive,” for the search to identify UI examples for this device. To broaden the results, application examples for the device were considered regardless of their place of use. Consequently, the term “public” was not included in the keywords. The search was restricted to results from the last five years, 2018–2023, as technology changes rapidly. Studies in either German or English were included. Another important criterion was at least one UI example figure within the publication. Without this, the analysis of the design would not be possible. Additionally, UI research using virtual, augmented, or extended reality was excluded as they require additional devices, and the examples’ complexity and designs differ from large physical interactive displays. Relevant databases for this literature analysis are IEEE¹, ACM DL², SpringerLink³, Scopus⁴, and the first 100 results (sorted by relevance) of Google Scholar⁵. For further clarification, the coverage of this literature search using the characteristics of Cooper [35] can be described as follows: The focus is on applications developed for large interactive displays, especially on the goal of integration. Further, a conceptual literature review with a neutral representation of application examples for large interactive displays is conducted. The coverage should be exhaustive and selective, providing various application examples. The audience of this study is specialized scholars who are also interested in an overview of large interactive display applications and the frequency of culturally relevant UI aspects.

Conceptualization of the Topic

A concept matrix [242] has been applied to support the interpretation of the results. For this matrix, the concepts must be identified as a first step. In this context, they should describe common UI aspects for large interactive displays, which are challenging to determine. Existing work promotes general UI aspects for web design [58], general culturally influenced UI elements [138], and standardized ISO norms, e.g., ISO 9241(-161). However, the focus of this work lies on the cultural relevance of UI aspects. As the UI elements by Marcus [138] summarize many factors on a high level, the list of UI aspects (Subsection 3.1.2, Table 3.1), previously derived from prior research focusing on Hofstede’s cultural dimensions and their differences regarding UI design preferences, will be used as they are precise and target-oriented. These 15 UI aspects serve as the concepts for the systematic literature review and were assessed regarding their existence or evaluability during the literature analysis using the following questions: “Does this UI aspect exist in this example?” and “Is it possible to evaluate this UI aspect in this example?” To answer these questions, screenshots of the applications and, if available, textual descriptions were reviewed to determine a yes or no answer, marking the concept as applicable or not.

¹<https://ieeexplore.ieee.org/>

²<https://dl.acm.org/>

³<https://link.springer.com/>

⁴<https://www.scopus.com>

⁵<https://scholar.google.com/>

The 15 UI aspects used as concepts for the literature review are as follows:

- | | |
|-----------------------------------|---|
| 1. Navigation | 9. Colors: colorfulness |
| 2. Functionalities | 10. Colors: saturation |
| 3. Content: level of detail | 11. Picture-to-text-ratio |
| 4. Content: structure | 12. Multimodality |
| 5. Content: density | 13. Informativeness (of colors, sounds, typography) |
| 6. Content: type | 14. Joyfulness, fun factor |
| 7. Feedback and error messages | 15. Gender representation |
| 8. Support, assistance, and hints | |

Literature Search

Considering the selection criteria and keywords described in the previous parts, Table 4.1 presents the literature search result in numbers: the total number of results, the number of articles chosen for the first inspection based on the title and viewing provided figures within the paper as well as the number of finally reviewed papers considered for the literature analysis and synthesis. Finally, the last column summarizes all references for the reviewed papers. Overall, 68 applications for large interactive displays could be identified and were used for further analysis. It should be noted that duplicate entries were ignored after the initial consideration for the first inspections.

Table 4.1.: Literature search overview with the number of results, papers for the first inspection, and finally included papers for review and their reference.

Database	Total Results	1 st Inspection	Reviewed Papers	References
IEEE	380	15	10	[3, 6, 21, 28, 104, 107, 123, 161, 227, 247]
ACM DL	262	48	24	[24, 32, 34, 45, 54, 60, 64, 66, 92, 109, 119, 125, 134, 147, 149, 155, 171, 173, 176, 177, 198, 212, 232, 243]
SpringerLink	301	12	6	[16, 38, 61, 120, 200, 241]
Scopus	449	30	19	[37, 39, 48, 102, 106, 130, 131, 132, 133, 148, 156, 165, 175, 185, 190, 201, 211, 213, 229]
GoogleScholar	100 (out of 2080)	13	9	[11, 69, 101, 105, 108, 121, 127, 164, 182]
Sum	1492	118	68	

Literature Analysis

The literature search results for this review, as presented in Table 4.1, were analyzed in the next step regarding the concepts, e.g., the 15 culturally relevant UI aspects. Each application was reviewed to determine whether the specific UI aspects could be evaluated or identified. This analysis emphasizes which UI aspects are more or less common for large interactive displays. Chapter B shows the entire table with the results of the analysis. The outcome of this analysis is displayed in Table 4.2, which shows the sum of the UI aspect's occurrence and its percentage share of the total applications reviewed. To better understand the UI aspect of informativeness, it is essential to add that it was mainly observed in the colors used and did not concern sounds or symbols. Therefore, it will be only associated with colors in the subsequent steps.

Table 4.2.: The result of the literature analysis with UI aspects, their sum of occurrence, and percentage share of total applications.

UI Aspect	Navigation	Functionalities	Level of Detail	Structure	Density
Sum	58	68	68	61	68
% of 68	85.29	100	100	89.71	100
UI Aspect	Content Type	Feedback	Support	Colorfulness	Saturation
Sum	66	2	24	64	58
% of 68	97.06	2.94	35.29	94.12	85.29
UI Aspect	Picture-Text-Ratio	Multimodality	Informativeness	Gender	Joyfulness
Sum	55	4	64	3	38
% of 68	80.88	5.88	94.12	4.41	55.88

Literature Synthesis

The result of the literature analysis can be further synthesized. On average, a UI aspect occurred 47.36 times within the examples, corresponding to 69.65%. Consequently, everything above that percentage is evaluated as a relevant UI aspect. This procedure does not consider any contextual requirements for a successful large interactive display application, but only identifies which aspects are mainly used in most use cases. Using the percentage of 69.65% as the first threshold, the five UI aspects feedback, support, multimodality, gender representation, and joyfulness are categorized as minor relevant for large interactive display applications. However, as the key UI aspects are targeted, only the highly relevant ones are included in the final result. Therefore, the remaining UI aspects are further categorized into relevant (69.65–90.00%) and highly relevant ($\geq 90.01\%$). This leads to a descending list of UI aspects and their relevance for large interactive displays:

- **highly relevant** ($\geq 90.01\%$): functionalities, level of detail, density, content type, colorfulness, informativeness of colors
- **relevant** ($\geq 69.65\% - < 90.01\%$): structure, navigation, saturation, picture-text-ratio
- **minor relevant** ($< 69.65\%$): joyfulness, support, multimodality, gender representation, feedback

This result represents the current significance of UI aspects in large interactive display applications based on their frequency of use. It does not imply that minor relevant UI aspects are not crucial for such applications; however, they are currently not a primary focus or part of many. As this thesis aims to derive insights beneficial for UI aspects used in almost all applications, the focus is solely on highly relevant key UI aspects in the next steps. Depending on the use cases in which the displays are deployed, some UI aspects are more or less important based on the context in which they are used.

Research Agenda

The results of the synthesized literature review were used to prioritize further research into the potential adaptation of UI aspects for large interactive displays. This analysis indicates that highly relevant UI aspects (functionalities, level of detail, density, content type, colorfulness, informativeness of colors) are primarily observed in application contexts. Therefore, it is most beneficial to focus on adapting and analyzing recommendations for these aspects in the first place as most applications benefit from insights. The other aspects are also important and will become even more essential to provide inclusivity (multimodality) or assistance. To identify whether intercultural adaptation is beneficial for large interactive displays, the restriction to key aspects is necessary to provide concise and precise results with the potential to expand to other concepts and categories of UI aspects.

REQ3: The personalization approach should focus on the **key** UI aspects that have been identified as most beneficial for large interactive displays.

4.2.2. General Adaptation Rules

Another use of the previous literature review result is to map the highly relevant UI aspects to Hofstede's cultural dimensions and use it to identify general adaptation rules. As a first step, the UI aspects are connected to the cultural dimensions (Figure 4.3) to identify the relations. This mapping has been done by comparing where the UI aspect has been derived from based on Table 3.1. For example, the UI aspect level of detail has been derived by analyzing design preferences of the cultural dimension PD. Consequently, this UI aspect is related to or depends on the value of the cultural dimension of PD. Figure 4.3 displays this relationship with a line between the UI aspect and the cultural dimension. Through this mapping, we can conclude that the dimension MAS is irrelevant to the key UI aspects for large interactive displays as none of

the six aspects is related to this cultural dimension. However, the dimension MAS must also be considered when expanding the focus on other UI aspects, e.g., structure. This mapping also shows that certain UI aspects are related to multiple cultural dimensions. For example, the level of detail is associated with PD and UA. This must be considered in future steps when finalizing adaptation rules as it is unclear which cultural dimension is of greater importance.

REQ4: A prioritization strategy must be identified in case a UI aspect is related to multiple cultural dimensions.

The mapping between UI aspects and cultural dimensions can be further concretized by considering the design preferences derived in Subsection 3.1.2. Therefore, parts of Table 3.1 are combined with the literature review result, and a new table with general adaptation rules is obtained (Table 4.3). This result only provides an overview and general design preferences for either high or low values in the cultural dimensions. It must be specified for application-tailored UI adaptations while considering context and purpose. For instance, the level of detail related to the PD cultural dimension leads to low information at first sight in the case of a high PD value. Besides the transformation into application-specific adaptation rules, deciding which adaptation degrees are suitable for the personalization objective is necessary.

REQ5: The adaptation degrees must align with the personalization objective and be considered by the personalization approach.

REQ6: The personalization approach must allow for application-specific adaptation rules that refine the general adaptation rules.

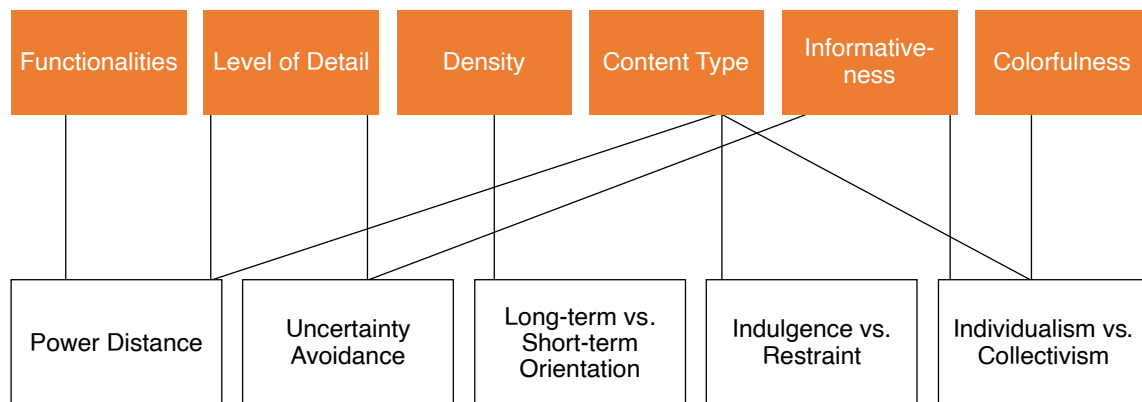


Figure 4.3.: Derived UI elements and their connection to cultural dimensions (based on Table 3.1).

Table 4.3.: General cultural adaptation rules for large interactive displays showing adaptation regarding low or high value of cultural dimensions (CD).

CD	Degree	UI Aspects					
		Functionalities	Level of Detail	Density	Content Type	Colorfulness	Informativeness
PD	low	high	high, less hierarchy		formal (leader, organization)		
	high	low (reduced choice)	low, strong hierarchy		informal (people in daily activities)		
IDV	low				formal (community and product-related)	many colors	traditional colors
	high				formal (focus on individuals)	monotonous colors	color-encoded information
UA	low		high, complex UI				color-encoded information
	high		low, strong hierarchy				redundant use of colors
LTO	low			low			
	high			high			
IND	low				formal (work, humorless)		
	high				informal (humorous, user-generated)		

4.3. Group Modeling

This chapter analyzes the requirements for successfully modeling intercultural group preferences. Therefore, this section derives the information necessary for group modeling based on known user modeling approaches for cultural values. It also discusses various group modeling strategies regarding their purpose and suitability.

4.3.1. Cultural User Modeling

Based on previous work by Reinecke [186], the approach of a cultural user model must be adapted and expanded for this thesis's purpose. According to [186, 188], the following information about a person is related to modeling their cultural background and impacts their UI design preferences:

- **Country & nationality:** according to effects of Hofstede's dimensions on UI (affects all UI aspects derived earlier)
- **Language:** objects in focus or embedded in a context
- **Reading/writing direction:** alignment of UI aspects
- **Age:** objects are in focus or embedded in a context, support levels, (non-)linear navigation
- **Education level:** support levels, navigational cues
- **Form of instruction:** (non-)linear navigation, support levels
- **Computer literacy:** support levels, navigational cues
- **Political orientation/social structure:** objects in focus or embedded in a context, level of details, information density, number of images, image types, (non-)linear navigation
- **Religion:** religious symbols, colorfulness, saturation
- **Gender:** impacts several UI aspects

Due to data minimization, only the data that is strongly required will be requested from the users. Accordingly, the user modeling data reported in [186] will be re-evaluated to assess its relevance to the key UI aspects identified in chapter Section 4.2, which are in the focus of the adaptive system. This also should address data privacy concerns by collecting solely necessary information from the users, which needs to be expanded when targeting other UI aspects. Therefore, only the user model aspects *country (residences) and nationalities*, due to the relevance for applying Hofstede's cultural dimensions, the *age (year of birth)*, for calculating the impact of residences on a user according to [186], and the *political orientation*, as it impacts the level of detail and density, are included in this work. Religion also impacts the UI aspect of colorfulness. However, the color schemes will not be adapted according to religious meaning. Consequently, this information will not be included in the revised cultural user model. Gender is

also related to several UI aspects, but it will only be used as a control variable as “culture can outweigh differences in gender” [186, p. 47]. Also, the study presented in [8] determined that distinguishing gender does not result in significant differences among male and female users. Moreover, some information was made optional to keep data gathering as short as possible: The *parents’ nationalities* is categorized as optional, where entries about a maximum of two people besides parents impacting the users’ lives, for example, grandparents, are allowed. Also, the political orientation is optional as it only affects the IDV cultural dimension and is already represented by this value [186, p. 60]. This reduced information about the users is required to calculate the cultural user profile in this context.

REQ7: All necessary information about each user of the intercultural group must be collected to generate an accurate cultural user model.

The computational approach for the cultural user profile presented in [186] serves as a reasonable basis but requires adaptation and expansion to consider all user-provided information. To consider residences and how they impact the cultural user model, the method described in [186, 188] is beneficial and, having been proven successful, is adapted to this work. The influence of each country, depending on the user’s age, is calculated and impacts the dimension scores. Therefore, the following two equations (Equation (4.1), Equation (4.2)) are used based on the approach from [186].

$$\text{influenceOfCountry}_N = \frac{\text{monthlyDurationOfStayInCountry}_N}{\text{ageInMonths}} \quad (4.1)$$

$$\text{userDimScore}_H = \sum_{i=1}^N \text{countryScore}_H \cdot \text{influenceOfCountry}_i \quad (4.2)$$

As mentioned, other information about the users is also gathered, including nationalities (own and of the parents) and, if submitted by the user, the political orientation. Unfortunately, prior work does not provide precise information on the extent and manner in which this information should be considered for calculating the cultural user model [186, 188]. However, they give an example with information about a user’s religion, weighted with 20% [186, pp. 62–63]. Based on the example within this previous approach, the user model calculation must be revised to consider all relevant information gathered for this work. As a result of this part, it is essential to identify a cultural user model by calculating values for all cultural dimensions and considering the information provided: Residences, nationalities, and political orientation.

REQ8: The calculation of the cultural user model must be updated to incorporate all relevant user-provided information.

4.3.2. Group Modeling Strategies

After identifying how to model users and their cultural backgrounds, it is necessary to determine the correct or most suitable group modeling strategy. The eleven aggregation strategies inspired by Social Choice Theory are the most common and basic strategies in group recommender systems [146]. These strategies have already been introduced in Subsection 3.2.4 and must be analyzed to determine whether and for which task they can be used for cultural dimension values. Their applicability is also discussed based on an analysis of a sample dataset containing the values of the cultural dimensions of the two most populated countries per continent [222]. The following summary describes how these strategies can be applied in relation to the cultural dimension values:

- **Plurality Voting:** As items are chosen and not necessarily their value, this method is applicable for ranking cultural dimensions.
- **Average:** Works mainly well for homogenous groups (according to [146]), can be used to calculate dimension values.
- **Multiplicative:** If a user has the value zero within a dimension, it will result in a zero for the overall dimension, as the result is the same as the average; this method will not be discussed further.
- **Borda Count:** As items are chosen and not necessarily their value, this method is applicable for ranking cultural dimensions.
- **Copeland Rule:** As items are chosen and not necessarily their value, this method is applicable for ranking cultural dimensions.
- **Approval Voting:** As items are chosen and not necessarily their value, this method is applicable for ranking cultural dimensions.
- **Least Misery:** This can be used to calculate the values of the dimensions for a group.
- **Most Pleasure:** This can be used to calculate the values of the dimensions for a group.
- **Average without Misery:** This can be used to calculate the values of the dimensions for a group.
- **Fairness:** This can be used to calculate the values of the dimensions for a group.
- **Most respected person:** This strategy prioritizes a user's preferences higher than others. We cannot say one user's preferences are more important than others. Thus, this strategy is irrelevant.

Considering the evaluation of these strategies, they can be classified further into the categories majority-based, consensus-based, and borderline aggregation functions [210]:

1. **Majority-based aggregation functions:** Plurality Voting, Borda Count, Copeland Rule, Approval Voting. These strategies could identify a ranking for cultural dimensions by considering how strongly the cultural dimension values are for each user and, thus, which cultural dimension is more relevant to the group by considering the most substantial values.
2. **Consensus-based / borderline aggregation functions:** Average, Multiplicative, Least Misery, Most Pleasure, Average without Misery, Fairness, Most Respected Person. With these strategies, a value for each cultural dimension can be calculated.

REQ9: The personalization approach must support the most suitable group modeling strategies for all necessary calculations.

4.4. Summary of Requirements

Based on the previous sections, the following list with vital requirements for the approach of intercultural personalization of large interactive displays in semi-public areas could be obtained:

- **REQ1:** Minimize user involvement: Adapt the UI to intercultural design preferences for a small group as independently as possible. Consider this constraint also during data acquisition.
- **REQ2:** Ensure a comprehensive approach by selecting a UI aspect from each design paradigm to incorporate various perspectives on personalization.
- **REQ3:** The personalization approach should focus on the **key** UI aspects that have been identified as most beneficial for large interactive displays.
- **REQ4:** A prioritization strategy must be identified in case a UI aspect is related to multiple cultural dimensions.
- **REQ5:** The adaptation degrees must align with the personalization objective and be considered by the personalization approach.
- **REQ6:** The personalization approach must allow for application-specific adaptation rules that refine the general adaptation rules.
- **REQ7:** All necessary information about each user of the intercultural group must be collected to generate an accurate cultural user model.
- **REQ8:** The calculation of the cultural user model must be updated to incorporate all relevant user-provided information.
- **REQ9:** The personalization approach must support the most suitable group modeling strategies for all necessary calculations.

5. An Approach to Intercultural Personalization of Large Interactive Displays

The overall objective of this approach is to provide a strategy for personalizing the UI of large interactive displays in semi-public areas, considering the intercultural design preferences of a small group. Therefore, the previous section summarized the requirements (Section 4.4) that this approach needs to fulfill. This chapter describes the approach, including a procedure for implementation and the corresponding system design. In addition, open questions and potential for improvement concerning the approach will be gathered. The presented approach is implemented exemplarily in the next part of this work to illustrate an application-specific transition and to derive answers for the identified open questions for iterative improvement.

5.1. Procedure

A structured procedure defining relevant steps is required to successfully implement a personalized UI for intercultural groups. This procedure serves as a foundation of the personalization approach, ensuring its applicability and transferability.

There are existing approaches promoted by related work that recommend similar procedures. A relevant one used to develop a recommender system covers these four steps [99]:

1. Acquire user preferences
2. Generate recommendations
3. Explain recommendations
4. Help choose the final recommendation

With the focus on the adaptation of websites, the following four steps for a successful implementation of a culturally adaptive UI have been identified [186]:

1. Acquire & store knowledge about users
2. Define & store initial adaptation rules
3. Implement UI that can transform adaptation rules
4. Refine adaptation rules

While the focus of these approaches is firmly on group recommender systems [99] and intelligent adaptive UI [186], not all of these steps are relevant to this work, and they overlook unique features that are crucial in this context. This thesis investigates how culturally based design preferences can be merged, considers unique features related to the context of large displays in semi-public areas, and how personalizing the UI design impacts the UX for such displays. Consequently, the following steps are derived, which describe the overall procedure for implementing the personalization approach for large interactive displays (illustrated in Figure 5.1):

1. **Acquisition & Cultural User Modeling:** Acquire and store user data to obtain cultural user profiles.
2. **Group Modeling:** Aggregate cultural user profiles into intercultural group profiles and rank cultural dimensions to enable determining the groups' UI design preferences.
3. **Identification of UI Adaptations:** Identify the group's UI design preferences based on the intercultural group profile. Compare the existing UI design with the group's design preferences to determine necessary UI adaptations.
4. **Group-Specific UI Implementation:** Based on the identified UI adaptations, implement and deploy the personalized UI version for the intercultural group.
5. **Verification & Evaluation:** After deployment, verify and evaluate whether the personalized UI version meets the group's needs or requires improvements.

The following parts explain each step in detail and propose ways to fulfill the requirements identified before in Chapter 4.

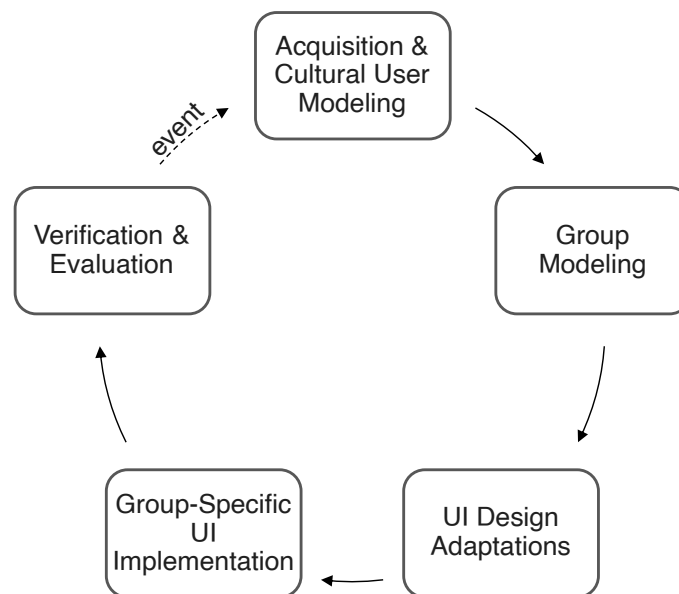


Figure 5.1.: Overall process to achieve an intercultural adaptive UI for large interactive displays in semi-public areas.

5.1.1. Acquisition & Cultural User Modeling

Before acquiring the necessary information about display users, it is essential to identify them first. As described in REQ1, the user involvement in this personalization approach should be as minimal as possible, which also concerns the user identification. As this personalization approach targets the users in the surroundings of the display, the office manager or operators of the display need to identify these persons. This depends strongly on the local conditions and office environments; hence, this is not the focus of this work. Thus, it is assumed that the operators and office managers can identify these users in the surroundings of the display by their position and the spatial allocation of the employees to office areas, and whether they are in the surroundings of a large interactive display. After deriving a list of users in the surroundings of the display, they are asked to fill out a survey to explicitly gather the required information [99] for calculating the user's cultural background. This is required, as other implicit methods, e.g., identifying someone's ethnicity or nationality using image processing, are highly bias-prone and imprecise, leading to stereotyping culture. To prevent and overcome these concerns, it is necessary to ask users explicitly about their cultural background by considering all the experiences they might have gathered through previous residences, parents' nationalities, etc. This approach has been developed and approved by Reinecke [186, 188]. It reduces the criticism of Hofstede's cultural dimensions being stereotyping by using nationalities and country barriers as cultural distinctions [46], as it considers way more information about the user than just their nationality. Consequently, the cultural user model requires minimal information about users, which partially fulfills requirement REQ1 and is discussed in the following paragraphs. Also, it is considered to put some information as optional due to information duplications and overlaps, as recommended in [186, p. 60]. The following list summarizes the required information (for more details on why these were selected, see Subsection 4.3.1) that needs to be collected explicitly from the users in the surroundings of the display:

- Nationalities (own)
- *(optional) Nationalities (parents or of influencing person)*
- Residences (current and duration, previous and duration)
- Year of birth (to calculate the age)
- Gender (control variable)
- *(optional) Political orientation*

After the users have submitted this data through the survey, which they can fill out on their own devices (mobile or desktop), the data is processed, and the cultural profiles of the users are calculated, which is required to fulfill REQ7. Therefore, the work by Reinecke [186] needs to be extended (REQ8), as only the influence of residences is concretized in their work. A solution for considering all information a user submitted through the survey is to calculate the cultural user

profile by considering, on the one hand, the impact of the nationalities reported by the users and, on the other hand, the previous residences in relation to the user's age.

Additionally, the political orientation, if submitted by the user, will impact the value of the cultural dimension IDV (individualism vs. collectivism) with +/-20%, similar to the reported weight in [186, pp. 62–63], which is the last computational step. More precisely, if users provide their information about political orientation, it will only be distinguished between “rather left”, “rather middle”, and “rather right” and will only impact the IDV value in the end, with -0.2 for “rather left” and +0.2 for “rather right”.

First, the impact of the own nationalities and residences is each weighted with 0.5 to show that even if a user has never lived for a long time in the country of their nationality, the nationality is still represented in this consideration. If a user has never lived in other countries, the weight of 0.5 for residences will represent the same values as the nationality. Next, the parents' nationalities are considered, weighing 0.3 for the overall cultural dimension values. Finally, the impact of the political orientation is considered for the IDV value with 0.2. An overview of the revised cultural user profile composition is displayed in Figure 5.2. The following formulas represent the computation of the revised cultural user model.



Figure 5.2.: Composition of the user profile with weighted shares.

Calculation of Countries' Influence

First, the influence factor of all countries, reported by the user for residences and nationalities, and the parents' nationalities, is calculated.

Influence of User's Residences For calculating the influence of a country based on the duration of the residence, the formula derived in [186] is applied (Equation (4.1)). As the users submit their year of birth, the age in months is calculated by:

$$\text{ageInMonths} = (\text{thisYear} - \text{yearOfBirth}) \times 12 \quad (5.1)$$

For each country i with a duration of stay in months and user's age in months, the influence from residences $I_{\text{residences},i}$ is:

$$I_{\text{residences},i} = \frac{\text{monthlyDurationOfStayInCountry}_i}{\text{ageInMonths}} \quad (5.2)$$

Influence of User's Nationalities To expand the previous calculation, the influence of the user nationalities is also considered for the impact of a country on the cultural user profile. Therefore, a similar formula calculates this influence factor $I_{\text{nationality},i}$ for each country in relation to the total number of nationalities:

$$I_{\text{nationality},i} = \frac{1}{\text{numberOfNationalities}} \quad (5.3)$$

Combined Influence of User's Residences and Nationality With a weight of 0.5 for residences and 0.5 for nationalities, the total influence of residences and nationalities is calculated by combining the influences for each country i :

$$\text{combinedInfluence}_i = 0.5 \cdot I_{\text{residences},i} + 0.5 \cdot I_{\text{nationality},i} \quad (5.4)$$

Normalized Combined Influence of Countries for User This combined influence, the user's nationalities and residences, is normalized to consider the influence of parents' nationalities with 0.3. Therefore, first, the combined influences for each country i are summarized to $\text{totalCombinedInfluence}$ for all countries N , before the combined influence is normalized for each country i in $\text{normalizedCombinedInfluence}_i$:

$$\text{totalCombinedInfluence} = \sum_{i=1}^N \text{combinedInfluence}_i \quad (5.5)$$

$$\text{normalizedCombinedInfluence}_i = \frac{\text{combinedInfluence}_i}{\text{totalCombinedInfluence}} \quad (5.6)$$

Influence of Parents' Nationalities This part calculates the impact of parents' nationalities (the total number of Parents Nationalities P), where each nationality p of a country is considered equally:

$$\text{influenceParentsNationalities}_p = \frac{1}{\text{numberOfParentsNationalities}} \quad (5.7)$$

Total Influence of each Country Finally, the calculated and normalized combined Influence of each user and the influence of parents' nationalities are combined for each country i with the weights 0.7 for the user's influence, through residences and nationalities, and 0.3 for parents' nationalities:

$$\begin{aligned} \text{finalInfluenceCountry}_i = & 0.7 \cdot \text{normalizedCombinedInfluence}_i \\ & + 0.3 \cdot \text{influenceParentsNationalities}_i \end{aligned} \quad (5.8)$$

Calculation of Cultural Dimension Values

After identifying the influence of each country on the user's cultural profile, the actual values are computed by the prior calculation of Reinecke [186], slightly adjusted, that calculates the

user profile values for each cultural dimension d and considering the previously identified total influence of each country i for all countries N :

$$\text{userDimScore}_d = \sum_{i=1}^N \text{countryScore}_{d,i} \cdot \text{finalInfluenceCountry}_i \quad (5.9)$$

Finally, the last step considers the political orientation if submitted. The political orientation is assumed to affect the cultural dimension IDV, with the following factors:

$$\text{adjustedIDV} = \text{userDimScore}_{\text{IDV}} \cdot \text{politicalOrientationFactor} \quad (5.10)$$

where $\text{politicalOrientationFactor}$ is:

- 1.2 if political orientation is "more left."
- 0.8 if political orientation is "more right."
- 1.0 otherwise.

The final result is a cultural user profile with values for each cultural dimension, considering residences (and duration), nationalities (own and parental), and political orientation. With these considerations and additional computations, the requirements REQ7 and REQ8 are fulfilled and considered in this personalization approach.

5.1.2. Group Modeling

After the cultural user profiles are calculated, the next step is to aggregate these profiles into a group profile. This step addresses requirements REQ4 and REQ9: Prioritizing cultural dimensions is required to decide on relevant UI adaptations when multiple cultural dimensions influence a UI aspect. Also, the most suitable group modeling strategy must be identified for aggregating cultural dimension values, which is also partially discussed in [222].

While traditional group recommender systems use item ratings to recommend new items, this is different when merging cultural user profiles. In this case, the "items" are the cultural dimensions, and the "ratings" are the values of cultural dimensions, which are different for each user. Subsequently, how such cultural dimension values can be aggregated needs to be investigated.

Another advantage of group modeling, merging cultural user profiles, is its positive impact on data privacy, which is a critical concern in personalization objectives. Since cultural user profiles are aggregated into a single intercultural group profile, it becomes impossible to extract or infer an individual's specific cultural dimension values and the corresponding cultural background they relate to. This ensures that personalization remains at the group level while preserving the anonymity of each user's cultural background and preferences, reducing the risk of re-identification and enhancing user privacy.

Ranking of Cultural Dimensions

As already classified in Subsection 4.3.2 and in [222], the strategies that can be applied for this purpose are plurality voting, Borda count, Copeland rule, and approval voting. Only three out of six key UI aspects within this personalization approach require the ranking of cultural dimensions, according to the general adaptation rules (Table 4.3), to enable the most suitable selection of adaptations. Consequently, the decision on which strategy to choose is based on the literature, and no comparison of several strategies is made. As stated in [146, p. 394], the Borda count strategy is one of the best-performing. In addition, applying Borda count to a sample dataset revealed the most promising, clear result for ranking cultural dimensions in contrast to the other strategies, which returned mixed ranks [222]. Consequently, the Borda count will be applied to identify the ranking of cultural dimensions. However, the cultural values must be rethought as they are: A low value does not describe a worse value than a high one; it is more about the differences between these values that depict different preferences. This is a unique feature of cultural dimension values that must be considered. Usually, a higher number is often related to better voting and stronger preferences in the aggregation strategies, which is not the case for cultural dimension values. Consequently, this approach proposes to consider the extent of cultural dimensions, as already introduced in [222], by calculating the absolute value of the difference from 50 (midpoint of the cultural dimensions), separating their meaning into below 50, considered as low, and above 50, considered as high. With this approach, it is possible to identify whether a user has more or less extreme values in the cultural dimensions that should be considered. It may imply which cultural dimension is more strongly represented among the group and, thus, more important for the group. For example, a user with a value of 20 in IDV (individualism) is lower and more highly impacted by this cultural dimension than another user with 40 in IDV. The extent can express this difference by recalculating the user's dimension scores d and identifying the absolute relevance:

$$\text{userDimAbsRelevance}_d = |50 - \text{userDimScore}_d| \quad (5.11)$$

This computation will transform the user values, and the Borda count strategy will identify the cultural dimensions with the most extreme values within the group. This strategy can fulfill the requirement REQ4 and partially REQ9.

Aggregation of Cultural Dimension Values

Summarized in Subsection 4.3.2 and discussed in [222], the strategies for aggregating and deriving actual values for the cultural dimensions are consensus-based or borderline. The latter are the least misery, most pleasure, and most respected person strategies, which focus on extreme extents, satisfying partially single individuals or no one in the group. This work's approach targets finding a solution for diverse preferences, so the consensus-based approaches are more interesting: average, multiplicative, average without misery, and fairness. Based on the literature [146, p. 394], the multiplicative strategy performed the best, as it satisfied all group participants. However, a cultural dimension value may be zero, diminishing the result by

multiplying everything by zero [222]. Consequently, this strategy will not be applied within this approach. For the average strategy, the homogeneity of the group impacts its success [146, p. 394]. In this work's context, it is suspected that the group is culturally diverse, which could result in mainly medium values for the cultural dimensions due to the strong differences, leading to a more borderline result that does not satisfy or dissatisfy anyone, as shown in [222]. Average without misery is a promising strategy, which performed quite well according to [146, p. 394] and also with a sample dataset of cultural dimension values [222], by explicitly ignoring items with dislike ratings. It might be a suitable solution for this use case, such as the fairness strategy. Both strategies seem promising as they support the natural decision-finding process within a group, as "users seem to care about avoiding misery and fairness" [146, p. 412] and also according to their application analysis for cultural dimension values, which revealed a mixture of diverse group preferences [222]. Subsequently, it needs to be identified which delivers a better result for intercultural groups. For complete fulfillment of requirement REQ9, this question still needs to be clarified. While the decision on which strategy works best is still open, the two strategies, average without misery and fairness, are considered within this personalization approach. The next paragraphs describe their application using cultural dimension values.

Average without Misery It is crucial to find a suitable threshold for this strategy. This threshold determines which values will be considered for calculating the average of the remaining values. However, it is vital to consider that the cultural dimension values are split at the midpoint 50: above 50 is regarded as a high extent in a cultural dimension, and below 50 is a low value in a cultural dimension. Consequently, the threshold must be applied ± 50 . The idea of excluding values close to 50 is that these values do not represent strongly pronounced preferences in contrast to others, which has been introduced briefly in earlier work [222] and is elaborated in more detail in this section. The threshold chosen for this personalization approach is 10, which means the users with values in cultural dimensions between 40 and 60, as this is the range of 50 ± 10 , are excluded from calculating the average within the group. The threshold is chosen as it ignores values in the middle area, focusing on the more extreme values of the group and putting them into the spotlight. This should ensure that extreme values are considered more strongly than values in the medium range. However, if all users have values in the middle range and are excluded from the aggregation, this strategy, with the threshold of 10, would be unable to calculate a result, producing a NaN (Not a Number). In this case, the value for this cultural dimension will be selected as 50, which is a medium value. Overall, the threshold does impact the aggregation strategies' result and, consequently, needs to be verified.

Fairness The fairness strategy [143] enables users to select one item that is most important for them or the highest ranked. In the case of two items with equal ratings, the *damage* this decision would make to the other group members is considered. While this is a fair strategy for generating a group profile, it must be adjusted to the characteristics of cultural dimension values – a need that was briefly introduced in earlier work [222] and is defined in more detail in this section. The first aspect to consider is how to identify the most vital item. In this case, the previous calculation

of the relevance of each cultural dimension for a user can be applied, which has been introduced in the ranking of cultural dimensions and is represented in Equation (5.11). With these relevance scores, it is easy to identify which cultural dimension is more or less pronounced for each user. As a result, the users select the most vital cultural dimension value, based on the ranking, one after the other, whereby only one value can be selected for each cultural dimension. With this approach, exactly six values can be selected for the six cultural dimensions.

For this strategy, it is recommended that if a user has several values with equal ranking, the other group members' values, "opinions," are taken into account by considering the "least misery" it can cause them [143, p. 104]. Additional calculations are conducted to transfer this consideration of the impact of "least misery" to others, the **damage**, when aggregating cultural dimension values. Besides using the relevance for each user to identify the highest ranked value, this work proposes to consider additionally the damage it can cause the other group members for all values in the range of -5 of the highest ranked value¹. This expands the proposed approach from considering the least misery for the overall group when there are equal values and only minor differences in the relevance values. The assumption is that a user would be ok with selecting values within a range of -5, as they still represent a strong preference. The following calculation for the damage has been identified, where for this purpose, the relevance score calculation needs to be adjusted by removing the transformation to absolute value, as the whole distances to each other need to be considered:

$$\text{userDimRelevance}_d = 50 - \text{userDimScore}_d \quad (5.12)$$

The average relevance score of all other group members i for each dimension d , is calculated using these adjusted relevance scores, with n as the total number of group members:

$$\text{averageRelevance}_d = \frac{\sum_{i=1}^{n-1} \text{userDimScore}_{i,d}}{n - 1} \quad (5.13)$$

Then, the difference between the relevance score of the user's cultural dimensions $\text{userDimRelevance}_d$ and the average of the other group members $\text{averageRelevance}_d$ is calculated for each dimension d :

$$\text{diffUserAvg}_d = \text{userDimRelevance}_d - \text{averageRelevance}_d \quad (5.14)$$

Finally, the damage score for each cultural dimension d of user u is computed as the ratio of the previous results and additionally considering the ranking of the highest relevance value (the overall ranking of cultural dimensions by the user) to promote its position:

$$\text{damageScore}_d = \frac{|\text{diffUserAvg}_d|}{|\text{userDimRelevance}_{u,d}| \cdot k} \quad (5.15)$$

where k is the ranking of the user's cultural dimension d , with $k \in [1, 6]$.

¹all dimensions with a relevance score of at least: $\text{highestUserDimRelevanceScore} - 5$

This calculation is conducted for all eligible cultural dimension values j , that a user still can choose and which are in the $\text{highestUserDimRelevanceScore} - 5$ range. The result is a percentage displaying the damage this decision would cause the other group members, depending on their differences. The value with the smallest percentage, the most negligible damage, is then selected as the choice of the current user:

$$\text{choice}_u = \arg \min_j (\text{damageScore}_j) \quad (5.16)$$

As described in [143, p. 104] and also in [222], the order impacts the result of the group modeling process. This is also the case when selecting cultural dimension values that represent design preferences. However, the order will be randomized to avoid additional complexity and influence factors.

With these two aggregation strategies, average without misery and fairness, it would be interesting to see which results in a better solution for merging cultural user profiles and deriving an intercultural UI design for large interactive displays. After comparing the results of these methods in an exemplary study and deriving the more suitable one, the requirement REQ9 can be sufficiently fulfilled. An overview of all relevant components for group modeling the intercultural design preferences based on the cultural user profiles is further provided by an ontology in Subsection 5.2.1.

5.1.3. Identification of User Interface Adaptations

The personalization of large interactive displays for intercultural groups in semi-public areas will focus on **adaptation**, which leads to no user involvement in the personalization of UI aspects. This objective fulfills the requirement REQ1 and needs validation, whether the autonomous adaptation of the UI aspects is successful in this case.

As already identified in Section 4.2, these six key UI aspects for large interactive displays are relevant for the adaptation: functionalities, density, level of detail, content type, colorfulness, and informativeness of colors. Mapping them to the personalization design paradigms [50], the approach considers various personalization perspectives demanded by requirement REQ2:

- **Commercial:** content type
- **Architectural:** level of detail, colorfulness, density
- **Relational:** informativeness of colors
- **Instrumental:** functionalities

With this mapping, the personalization approach focuses slightly more on architectural design components. However, it considers the derived key UI aspects throughout, which fulfill requirement REQ3. The general adaptation rules are identified and summarized in Table 4.3 and describe the various adaptation degrees for each cultural dimension abstractly. Based on the cultural dimension ranking, calculated with Borda count for the group, the UI design preferences

and the most suitable adaptations can be selected from that table by comparing the current UI classification.

The current adaptation table considers two extents of the cultural dimensions, low and high. These adaptation degrees are binary and do not differentiate preferences strongly. They are expanded to **low, medium, and high** for a more precise personalization according to the group's values. These degrees have proven successful in similar approaches [186]. With this decision, the requirement REQ5 is considered.

Another part of this procedure is interpreting these general adaptation rules into application-specific ones. Therefore, the following questions need to be answered by experts or a focus group of the target application:

1. What are the culturally relevant UI aspects within the application?
2. How can the current UI design be classified regarding the adaptation degrees: low, medium, and high?
3. What changes are required to achieve other adaptation degrees?

After identifying the application-specific adaptation rules, the requirement REQ6 can be fulfilled. Combining this result with the previously identified group model derives UI design preferences according to the group's intercultural profile. For example, assuming group A has the following result from the group modeling process:

- **Ranking:** IDV, PD, UA, MAS, IND, LTO
- **Cultural dimension values:** PD = 74, IDV = 28, MAS = 67, UA = 30, LTO = 52, IND = 67

Based on the general adaptation rules, as there is currently no application-specific example, the following UI design preferences will be determined for this group profile:

- **Functionalities:** The cultural dimension PD is related to functionalities; as the group has a high value of 74, the functionalities will be low, with only a reduced choice of functionalities.
- **Level of detail:** This dimension is related to PD and UA; according to the group's ranking, PD is higher ranked than UA; thus, the adaptation rules of PD are selected. As the group has a high value of 74 for PD, the level of detail should be low, which results in a strong hierarchy and little information at first sight.
- **Density:** This UI aspect has only one relation to UA; as the group's value of UA is low, with 30, the density should be low.
- **Content type:** Here, the ranking of cultural dimensions is required, as PD, IDV, and IND are relevant for this UI aspect. For this group, IDV is the highest ranked; thus, the IDV value of the group with 28 is low, and the preferred content type for this group is formal and community-related.

- **Colorfulness:** For this UI aspect, the low IDV value of the group with 28 leads to recommending a colorful UI with many different colors.
- **Informativeness:** As this UI aspect is related to IDV and UA, the ranking displays that IDV with the low value is selected for this group, leading to using more traditional colors with less color-encoding information.

The final general recommendations for the group's UI design are the following, which must be transferred and further concretized by an application-specific interpretation:

- Reduce functionalities to a minimum.
- Reduce the level of detail a user can see at first sight and implement a strong hierarchy to explore the content.
- Use a low density for the UI to avoid overstraining.
- Mainly display formal content with information about the community and products.
- Use many different colors to achieve a highly colorful UI.
- For color selection, use more traditional colors with less color-encoded information.

The derived design preferences and recommendations according to the intercultural group profiles must align with the application-specific UI design. Comparing the identified degrees and recommendations for each UI aspect with the current application classification will show which UI aspects differ and must be adapted to the group's preferences. As an example, assume the following application-specific classification for the UI aspects and compare it to the degree of the group's preferences:

- **Functionalities:** current UI – low, group preference – low: No adaptation required.
- **Level of detail:** current UI – high, group preference – low: Reduce the level of detail by increasing user interactions necessary to receive all relevant information.
- **Density:** current UI – low, group preference – low: No adaptation required.
- **Content type:** current UI – a mixture of formal and informal content, group preference – formal, community-related: Remove informal content and focus on formal, community-related content.
- **Colorfulness:** current UI – low, group preference – high: Increase the number of colors and use more contrasting colors.
- **Informativeness:** current UI – low, group preference – low: No adaptation required; however, as colorfulness changes to high, consider that colors used should be traditional/neutral and no color-encoding by repetitive use.

The comparison derived shows which UI aspects differ and must be adapted to suit the group's design preferences. The next step is implementing these differences and deploying a new UI version.

5.1.4. Group-Specific User Interface Implementation

This step covers implementing UI adaptations, resulting in a UI version personalized for an intercultural group. Therefore, the UI adaptations relevant to each group profile must be implemented, which have been identified by comparing the current UI with the intercultural group profile in the previous step. The application implements or changes these UI aspects using configuration files with modular and adaptable settings. An overview of all relevant components and aspects for determining the pertinent UI adaptations for the group is depicted as an ontology in Subsection 5.2.2. With the deployment of the group-specific UI, the result covers all previously derived requirements.

5.1.5. Verification & Evaluation

Finally, the personalized UI version for large interactive displays should be regularly verified and evaluated. In case of an event, the approach needs to be applied again. Such events include user group changes and identified application improvements that are affected by the personalization approach.

Changes in user groups strongly depend on the contextual situation where the semi-public display is deployed and can be irregular, yearly, monthly, daily, etc. If a working group or department has a particular working area assigned, the corresponding employees would be considered for the whole procedure. A renewal will be required if there are personnel changes, a new employee joins the team, or an employee leaves. Another example is if the users in the display's surroundings change daily, the whole procedure must be conducted daily, resulting in a new UI design every day. This could confuse the users; thus, an additional explanation of how the UI has been derived would be required to ensure acceptance. However, explaining the UI adaptations is not within the scope of this approach.

The actual verification and evaluation of the UI versions deployed can either be implicit, through analyzing interaction data, or explicit, through asking users to rate the UI design. In addition, various UX evaluations can also be conducted to derive in-depth insights regarding the approach's success and identify improvements within the application-specific implementation. Identifying negative aspects during the evaluation that hamper the UX would lead to adjustments of the personalization approach and the repetition of the updated approach.

5.2. Ontologies

Ontologies are widely used to structure components and their relations in several domains. In recommender systems and adaptive technology, ontologies facilitate the description of key components when designing such systems. They are defined as: "an ontology is a formal explicit description of concepts in a domain of discourse (classes (sometimes called concepts)), properties of each concept describing various features and attributes of the concept (slots (sometimes called roles or properties)), and restrictions on slots (facets (sometimes called role

restrictions)). An ontology together with a set of individual instances of classes constitutes a knowledge base.” [169]

This section presents the two ontologies developed for this work by adapting and extending existing models to support this work’s approach to intercultural personalization of large interactive displays in semi-public areas. They aim to provide a structured representation of relevant information, ensuring a systematic foundation for implementing the personalization approach by defining key concepts (classes), relations, and properties. The first ontology describes essential concepts and properties for successful group modeling of cultural user profiles to derive a group profile representing intercultural UI design preferences. This includes required user information, relationships, and group modeling strategies. The second ontology extends this by connecting group profiles and potential adaptations of key UI aspects relevant to large interactive displays. Such connections represent group-specific UI versions. Both ontologies were developed using the seven-step approach by Noy and McGuinness [169], which includes the following four tasks:

- Define the classes in the ontology
- Arrange the classes in a taxonomic hierarchy (subclass-superclass)
- Define slots and describe allowed values for these slots
- Fill in the values for slots for instances

Since these ontologies are designed as a conceptual part of the approach rather than fully instantiated models, the final step, entering instances with values and data, is not applied. Instead, they provide a high-level structural overview to support understanding of the personalization approach by facilitating a representation of all relevant aspects. They ensure a shared understanding of the information structure and relations, aligning with the principle that ontologies help “share [a] common understanding of the structure of information” [169].

5.2.1. Group Modeling Ontology

This ontology was created to understand the relations between the user and the group model better. It describes the required user information and its use within the group modeling process.

Step 1: Determine the domain and scope of the ontology

The ontology is meant to be used by researchers and practitioners interested in understanding the relationship between the user and group model concerning cultural dimension values. Its purpose is to provide information about similarities and dependencies by describing what is vital for generating group profiles based on cultural values for intercultural adaptation, particularly for large semi-public displays. The competency questions that this ontology can answer are:

- What is essential information about users used to calculate a cultural user model?
- How are several user models combined in group models?
- What are the characteristics of a group model, and which information is included?

- How are user and group models related to cultural dimensions?
- What aggregation method is used for calculating user groups' cultural dimension values?

Step 2: Consider reusing existing ontologies

An ontology for a cultural user model has been developed by Reinecke [186, pp. 56–63], which can be used as a basis but needs modifications to meet this work's objectives. The elements of the existing cultural user model [186] have already been discussed in Subsection 4.3.1. The main difference between the ontology presented there and in this work is that it only covers the cultural user profile of a single user. This work builds upon this approach and expands the ontology to represent a group of users. As already discussed, many aspects considered in the cultural user model ontology [186] are unnecessary to gather about individuals due to data minimization, as they are not required for personalizing the key UI aspects. Consequently, the user model is reduced to the information summarized in section Subsection 4.3.1. In addition, essential attributes and aspects, such as relations to a group model, must be added to the existing ontology [186, pp. 56–63].

Step 3: Enumerate important terms in the ontology

The vital terms used in this ontology are the `user`, which represents a single user and their cultural background, and the `group`, which combines several single user profiles. The user's cultural background considers `residences`, current and former, including the duration, and `nationalities`, the own and parental ones. Additionally, the user profile requires information about `gender`, `age`, and `political orientation`. Countries are connected to the `nationalities` and `residences` of the user's cultural background and are related to `cultural dimensions`, as each country has values for the `cultural dimensions`. Based on this information, the group has an `intercultural profile` which contains the aggregation method, the aggregation result (cultural dimension values), and the ranking of cultural dimensions.

Step 4: Define the classes and the class hierarchy

The ontology requires the following classes: `Group`, `user`, `gender`, `residences`, `nationalities`, `country`, `cultural dimensions`, and `intercultural profile`. These classes have the following hierarchy:

- A group contains several users.
- A user belongs to at least one group.
- Gender, residences, and nationalities are subclasses of a user.
- Residences and nationalities are related to a country and its cultural dimension values.
- An intercultural profile is a subclass of a group.
- An intercultural profile, a user, and a country have values for cultural dimensions.

Step 5: Define the properties of classes - slots & Step 6: Define the facets of the slots

This step describes the properties for each class and the types of properties. It is always expressed as property: type.

A User has the properties hasUserID: int, hasCulturalValues: enum, hasAge: int, hasPoliticalOrientation: string. The class Gender has the properties genderType: {male, female, divers}. The class Residences has properties hasCurrentResidence: Country, hasFormerResidences: Countries, duration: double. The class Nationalities has the properties hasNationalities: Country, hasNationalitiesMother: Country, hasNationalitiesFather: Country. The class Country has the properties hasName: string, and the class CulturalDimensions has the properties powerDistance: float, individualism: float, masculinity: float, uncertaintyAvoid: float, longTermOrient: float, indulgence: float. The class Group has the properties hasGroupID: int, hasUsers: UserIDs. The class InterculturalProfile has the properties hasRankingResult: sortedListDim, hasAggregationMethod: string, hasCulturalValues: enum.

The result of this process is the ontology displayed in Figure 5.3, which has been implemented in OWL (OntologyWebLanguage [153]), a semantic web standard, using *Protégé*² and visualized similar to a UML using OWLGrEd.

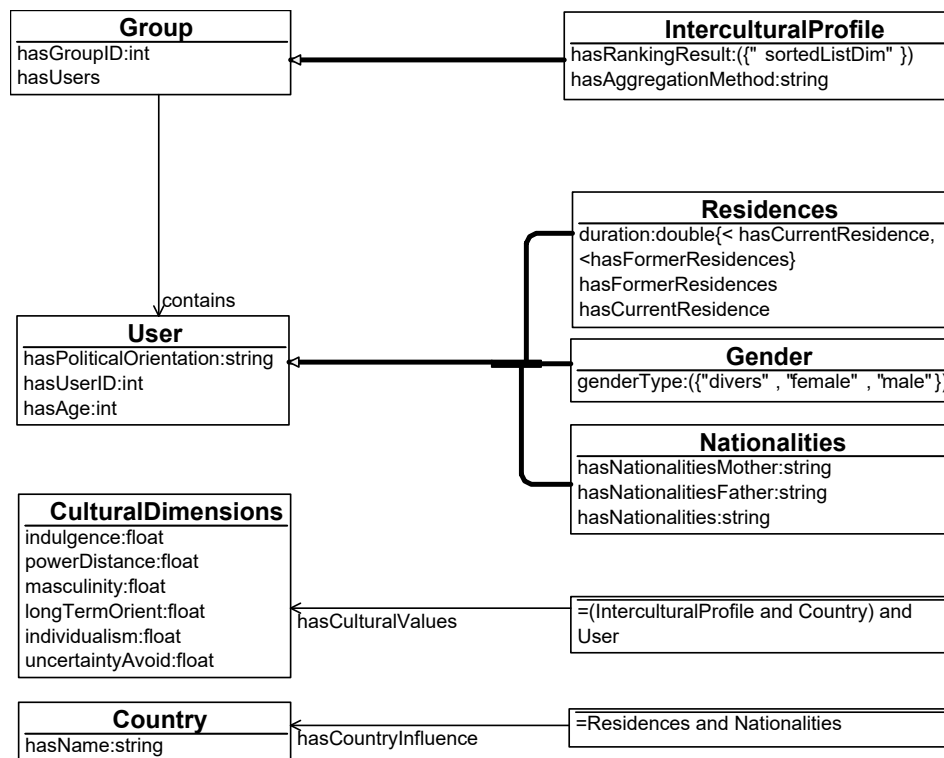


Figure 5.3.: Group model ontology that describes the relations and components necessary to derive an intercultural group profile.

²<https://protege.stanford.edu/>

5.2.2. User Interface Adaptation Ontology

For the intercultural adaptation of large interactive displays, another ontology is necessary to describe how the actual UI aspects are adapted and what relations exist with the group model and other parts required for personalizing such a system.

Step 1: Determine the domain and scope of the ontology

This ontology will describe how the UI of large interactive displays can be adapted to a previously identified group profile. It consists of potential UI aspects and how they can be adapted, as well as a group profile that represents the group's UI preferences based on the values for cultural dimensions. It provides an overview of relevant aspects required for personalizing large interactive displays regarding a group's intercultural preferences in semi-public areas. The purpose is to create a shared understanding of relations and information needed for researchers and practitioners targeting a more culturally sensitive UI. Therefore, it builds upon the previously identified group model and demonstrates how it can be used to derive intercultural adaptations for the UI design. The competency questions of this ontology are:

- What are the adaptations of the large semi-public display relevant for this user group?
- How can large, interactive, semi-public displays be adapted according to a group's preferences?
- What needs to be adapted if the group has a high value for PD?
- To what extent can density be adapted, and to which cultural dimension is this related?

Step 2: Consider reusing existing ontologies

In the work of Reinecke [186, pp. 56–63], an adaptation ontology for a website application has been developed. While the UI structure of websites and large interactive displays differ, most of the presented ontology can not be used as such. Still, it will be used as motivation and validation of whether all relevant aspects have been considered.

Step 3: Enumerate important terms in the ontology

As the adaptation focuses on the user interface, it is an essential part of the ontology. Further, the UI aspects are relevant for the adaptation, which can partially be classified into UI aspects concerning the content: density, type, and level of detail. Another classification would be about colors: colorfulness and informativeness. The access to functionalities is also relevant, but thematically not assignable to content or colors. Another vital aspect is the group profile, which represents the design preferences of the group through their intercultural profile, which contains information about the aggregation method, the ranking of cultural dimensions, and determined values for the cultural dimensions.

Step 4: Define the classes and the class hierarchy

The intercultural adaptation ontology consists of the following classes: User interface, content, colors, group, intercultural profile, and cultural dimensions. They have the following relations and hierarchies:

- The user interface has the subclass's content and colors.
- The user interface is adapted for a particular group.
- The group has a certain intercultural profile with cultural values for cultural dimensions.

Step 5: Define the properties of classes - slots & Step 6: Define the facets of the slots

This step describes the properties for each class and the types of properties. It is always expressed as: `property: type`.

The `UserInterface` class has the properties `hasAdaptationID: int`, `hasFunctionalities: {high, medium, low}`. The class `Content` has the properties `hasLevelOfDetail: {high, medium, low}`, `hasDensity: {high, medium, low}`, `hasType: {formal, formalOnly, informal}`. The class `Colors` has the properties `hasInformativeness: {high, medium, low}`, and `hasColorfulness: {high, medium, low}`. The `Group` class has the property `hasGroupID: int`. The `InterculturalProfile` includes the properties `hasAggregationMethod: string`, and `hasRankingResult: sortedList-Dim`. To complete the intercultural profile, the cultural values are represented by the class `CulturalDimensions`, which has the properties `powerDistance: float`, `individualism: float`, `masculinity: float`, `uncertaintyAvoid: float`, `longTermOrient: float`, and `indulgence: float`.

The intercultural adaptation ontology is represented by Figure 5.4, which has been implemented in OWL (Web Ontology Language [153]), a semantic web standard, using *Protégé*³ and visualized similar to a UML using OWLGrEd.

5.3. System Architecture

A system architecture (Figure 5.5) provides an overview of the vital components a system requires, in this context, essential for the intercultural adaptive UI of large interactive displays:

- **Large Interactive Display:** The large interactive display is positioned in a semi-public area and enables touch interactions. The UI displays an application that should provide information about the employees working in that area and what is happening in the company. Single or multiple users can interact with the UI, simultaneously or sequentially.
- **Users:** The users are people and employees located in the surroundings of the display location. These are people with offices in the immediate vicinity or who often visit the area.

³<https://protege.stanford.edu/>

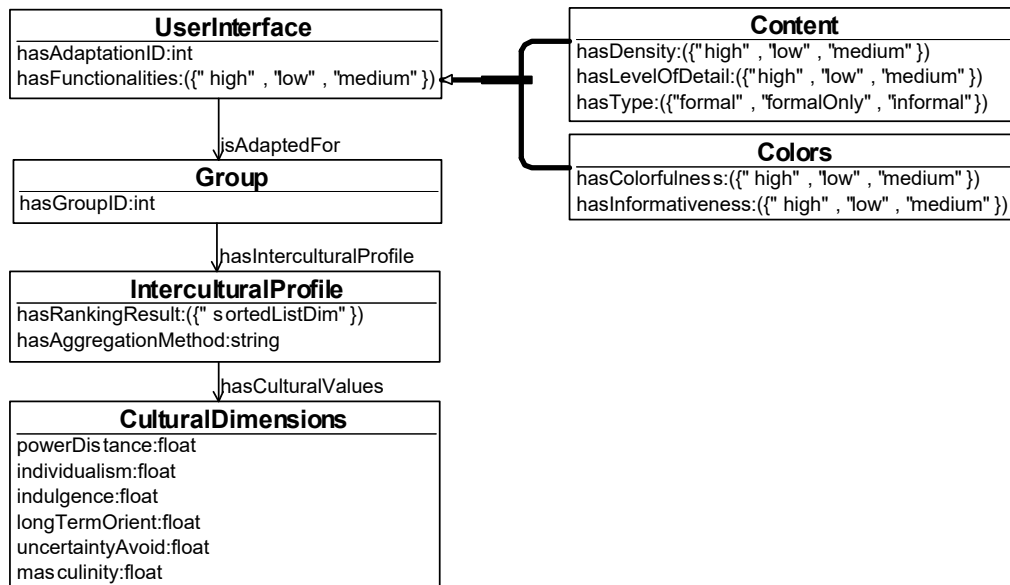


Figure 5.4.: Intercultural adaptation ontology that describes the relations and components necessary to adapt the UI of large interactive displays for an intercultural group.

- **Survey – Data acquisition:** Information about the users is required to personalize the UI and is vital to calculate the cultural user profile for the users. The users provide this data through a survey using their own devices, mobile or desktop. As a result, cultural user profiles are calculated and stored in a user database (DB).
- **Group Modeling:** Based on the user DB, the identified user profiles are aggregated to a group profile using a suitable aggregation method. In addition, a ranking of the cultural dimensions is calculated. The group profile is then stored in the group DB and consists of the aggregation result with values for cultural dimensions, the ranking result, and the user IDs that have been merged for the group.
- **UI Aspects:** All potential adaptations for the UI aspects with all possible extents, mainly {high, medium, low}, are stored in another DB.
- **Identifying UI Adaptations:** For each group profile, the most suitable adaptations are identified from the potential ones using a rule-based approach.
- **Adapted UI Versions:** The identified adaptations for the group profile are then implemented for the large interactive display, which results in another improved UI version personalized for the group.

The underlying technologies used for these system components and their communication depend on the overall enterprise IT environment and the application development.

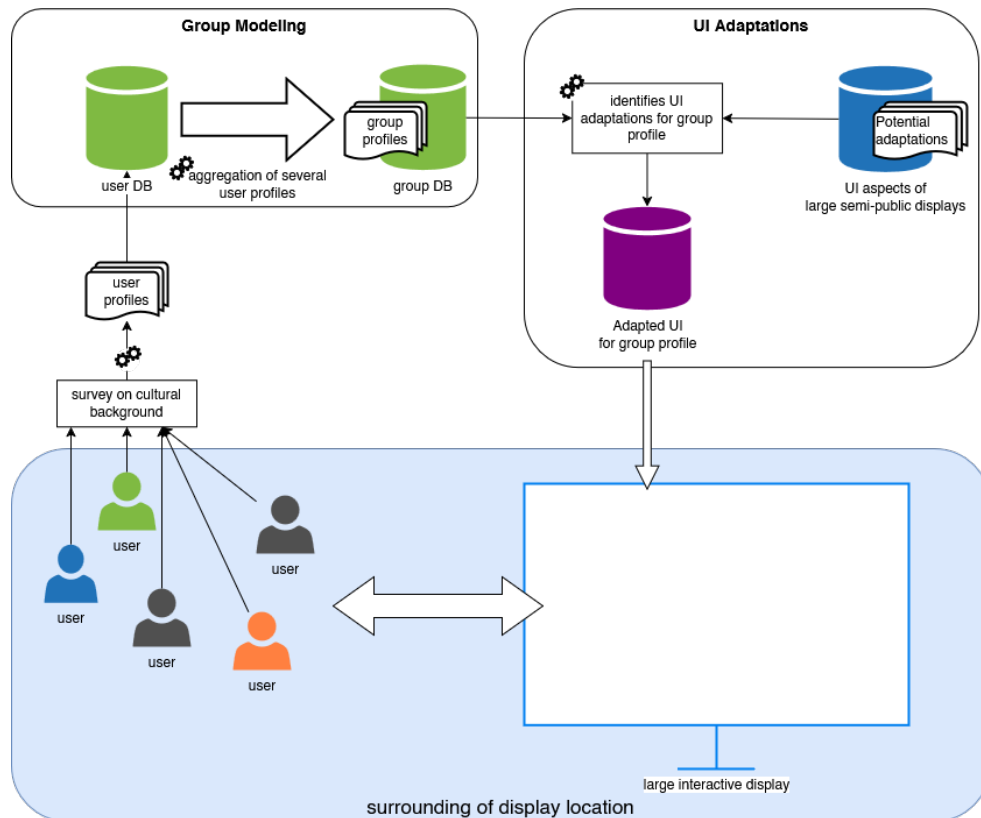


Figure 5.5.: The system architecture of vital components and relations between a large interactive display, potential users, data acquisition, user and group modeling, and the derivation of group-tailored UI adaptations resulting in a personalized UI version.

5.4. Open Questions

This part summarizes open questions that remain unclear within certain steps proposed in the approach's procedure. The exemplary implementation investigates these questions and derives answers by evaluating the approach and its procedure as a whole.

Group Modeling Several aggregation strategies can be applied in group modeling. However, an open question is which strategy leads to a better result for the group. The two promising approaches described, average without misery and fairness, should therefore be compared in the evaluation to determine which results in a more suitable UI version for an intercultural group. This comparative evaluation builds upon a possible way forward outlined in previous work [222].

Impact on UX The personalization through adaptation of large interactive displays for intercultural groups targets a more culture-sensitive design. For which UI aspects the personalization works well and whether the adaptation is a suitable approach to positively impact the UX, still must be verified.

Personalization Approach Validation The overall approach must be verified to identify if all requirements are met and if the approach fulfills all aspects relevant for an adaptive system that serves as a basis for future developments by additionally considering intelligent features, such as improving adaptation recommendation through collaborative filtering, considering implicit interaction data, etc.

5.5. Summary

This section presents a high-level overview of the previously described approach, including the procedure, the system architecture, and ontologies, which are essential for understanding the personalization approach in depth. The approach for personalizing the UI of large interactive displays for intercultural groups in semi-public areas consists of the following five-step procedure, visualized in Figure 5.1:

1. **Acquisition & Cultural User Modeling:** Identify ordinary users in the vicinity of the large interactive display, which are then assumed to be frequent users. Collect the necessary information about them to calculate the cultural user profile (Subsection 5.1.1). This step derives several cultural user profiles with values for Hofstede's cultural dimensions.
2. **Group Modeling:** Aggregate the previously identified cultural user profiles and derive an intercultural group profile. This includes a ranking for cultural dimensions and the actual aggregated values for each cultural dimension of Hofstede (Subsection 5.1.2). However, the most suitable aggregation strategy, average without misery or fairness, still needs to be identified.
3. **Identification of UI Adaptations:** Derive application-specific adaptation rules by transferring the general adaptation rules for the key UI aspects. Use expert workshops or focus groups to identify the application-specific UI aspects, classify the current UI design, and identify other adaptation degrees. Combine the previously identified group profile with the application-specific adaptation rules and identify group-specific design preferences. Derive UI adaptations relevant to the intercultural group profile by comparing the current UI design to the group's design preferences and identifying necessary adjustments (Subsection 5.1.3).
4. **Group-Specific UI Implementation:** Adjust and implement the UI version to achieve a group-specific UI (Subsection 5.1.4).
5. **Verification & Evaluation:** The personalized UI design must be regularly reviewed and improved to ensure it fits the group and meets their preferences. This strongly depends on various contextual variables (Subsection 5.1.5). Certain events can lead to repeated procedure execution to derive an up-to-date, personalized UI version.

Concerning the entire approach, it is helpful to identify an application-specific system architecture, including the technologies and peculiarities impacting the implementation. Therefore, the provided general architecture in Section 5.3 can be beneficial to build upon. Moreover, the ontologies (Section 5.2) further provide guidance in considering all relevant aspects for the personalization approach.

The next part of this thesis exemplifies this approach through its implementation in an application-specific context to evaluate, verify, and improve it. This implementation contributed to addressing the previously reported open questions concerning the approach. The subsequent evaluation investigates whether this approach effectively personalizes large interactive displays for an intercultural group. Based on the findings, a fundamental personalization approach has been developed. It can be further expanded with additional steps to make it an intelligent adaptive system or a group recommender system based on learning mechanisms for UI designs. These developments would rely on feedback mechanisms to evaluate the user's satisfaction with recommendations to re-evaluate and improve the derived group recommendations. Nonetheless, the approach's ability to merge cultural design preferences and identify suitable UI adaptations must first be verified.

Part III.

Evaluation

6. Evaluation Overview

This chapter explains the study design and provides an overview of the evaluation of the proposed personalization approach. Therefore, the first part deeply discusses the study design and all associated requirements. The second part summarizes the data collection by describing the data collected and providing an overview of the material gathered, which is then used for the data analysis. This chapter provides contextual information vital to understanding the overall evaluation and how the results were determined.

6.1. Study Design

To investigate whether the intercultural personalization of a large interactive display for a group in semi-public areas, as proposed in Chapter 5 is successful and considers various perspectives on personalization, a laboratory evaluation focusing on the UI adaptation of an application is conducted. The application used for this purpose is **CommunityMirrors** [110], a network of large interactive displays deployed at the University of the Bundeswehr Munich. As the CommunityMirror application does not have classical tasks that can be tested or improved in such settings required for usability testing, the evaluation focuses more on elaborating the impact on the UX of such displays using mixed methods, with a stronger focus on qualitative ones. This evaluation should lead to insightful findings to better understand why a person liked or disliked some UI parts and, consequently, whether the personalization approach is successful. This is supported by the privacy of a laboratory environment and individual UX sessions, as no foreign observers pass by. In contrast to exclusively quantitative measurements for UX, qualitative methods dig deep into identifying what users think or perceive during the interaction and enable a better understanding of the adaptation's impact on the user's interaction. Moreover, it helps demarcate irrelevant comments and opinions about aspects that have not been in focus of the adaptations from the relevant ones. The adaptation of the UI leads to many different versions, which further increases the complexity of the evaluation. Thus, the scope needs to be selected carefully. Conducting mainly qualitative research limits possibilities concerning the number of participants. It leads to exemplarily conducting the proposed personalization approach, including group modeling and identifying intercultural group-specific UI versions, for **four groups** with each **six participants**. Six people per group exemplarily display a small working group, and it ensures that in the group modeling method of fairness, at least everyone will have the chance to select one aspect that they prefer according to their cultural profile, as only six values can be chosen for the six cultural dimensions.

The study aims to evaluate and verify the personalization approach, identify improvements, and answer the open questions. In detail, it will reveal the most suitable group modeling strategy, how the cultural design preferences of multiple users can be aggregated by comparing two aggregation methods (average without misery and fairness), and investigate how large interactive displays in semi-public areas can be personalized through adapting six key UI aspects of large interactive displays: Functionality, level of detail, content type, content density, colorfulness, and informativeness of colors. Intercultural adaptations of a UI need to be tested to make more target-oriented design decisions and investigate whether this increases the UX with such displays. Overall, this evaluation implements the proposed personalization approach (Chapter 5), derives answers for open questions, and validates its transferability to an application.

6.1.1. Methodology

The evaluation applies a mixed methods approach, with a primary focus on qualitative methods, as quantitative data is not significant enough due to the limited number of six participants per group. The study's methods are think-aloud sessions, semi-structured interviews, and a user experience questionnaire short (UEQ-S) after interacting with each UI version. However, the study's strength is clearly within the qualitative data, as the UEQ-S can only provide a rough estimate. It has limited data sets, with six per group, and is not significantly meaningful on its own. Combining both will show that the qualitative data provides much more details that may or may not agree with the UEQ-S result, emphasizing the advantage of the qualitative methods. The sequence of the UI versions provided to the participants for the think-aloud phase remains the same for each participant throughout the evaluation: first, baseline (current UI), then version 1 (average without misery), and finally, version 2 (fairness). There is no advantage in mixing the sequence due to focusing mainly on qualitative methods and the limited number of participants. Also, the participants were not deceived about which version was the baseline and the adapted versions, as the objective was to compare and discuss their differences. The qualitative methods further support this approach and enable a detailed understanding of why some aspects were liked or disliked. Figure 6.1 displays the on-site evaluation and how the methods were applied.

Mixed methods research applies qualitative and quantitative data collection mechanisms to gather the required data for answering the research questions [40, 126]. In this study, the qualitative methods were think-aloud and semi-structured interviews, and the quantitative method was the UEQ-S, which should provide a rough direction.

In detail, think-aloud is a qualitative approach where users are asked to express their thoughts and opinions while interacting with the system [19, 216]. It enables an in-depth understanding of how they perceive the interaction with the UI and what may still be bothering them.

The semi-structured interview uses predefined questions and categories that are discussed with the participant to identify opinions and perceptions from the users [19]. This is especially helpful when comparing UI versions and discussing the participants' experiences from the think-aloud sessions.

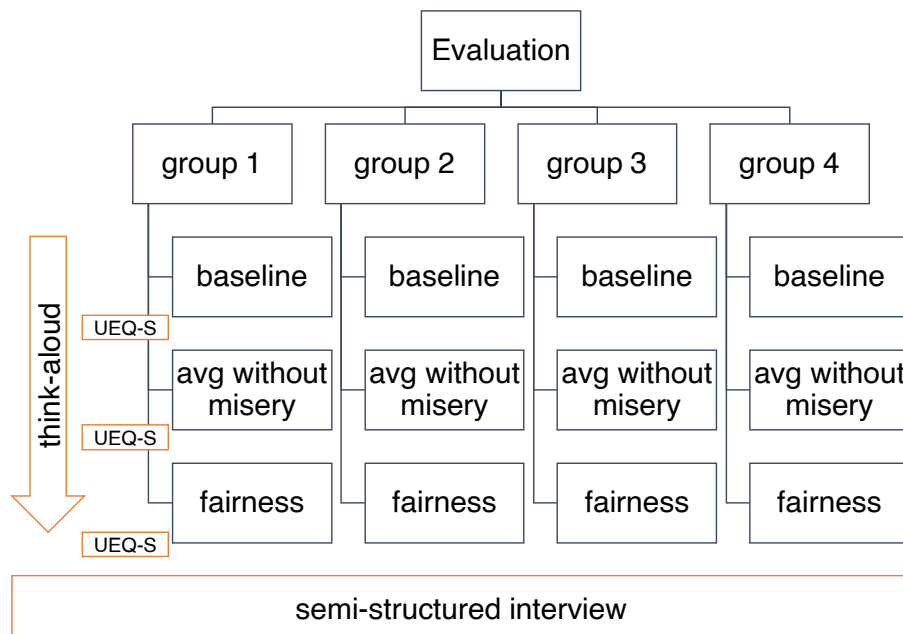


Figure 6.1.: Overview of the evaluation procedure and applied methods in orange rectangles. (avg without misery = average without misery)

The recordings from think-aloud and the semi-structured interviews are transcribed for further analysis. These transcripts are then used to extract findings and answers to the stated research questions. However, not all transcripts were equally important: The ones from the think-aloud sessions contained many comments and opinions concerning the overall application, with only partially relevant information about the key UI aspects pertinent to the personalization approach. Therefore, the focus for interpreting the transcripts was put on the semi-structured interview transcripts, which were examined by applying coding analysis, as the interview was much more focused on comparing and identifying likes and dislikes concerning the UI adaptations relevant to this approach.

The UEQ-S [209] is the short version of the widely used user experience questionnaire (UEQ) that subjectively measures the UX of products. Usually, the UEQ [124, 207, 208] consists of 26 approved items covering the overall attractiveness and then distinguishing between pragmatic (perspicuity, efficiency, dependability) and hedonic (stimulation, novelty) quality of the UX. As filling out the full UEQ was expected to be too immersive for the on-site evaluation, and the quantitative data gathered through this questionnaire should only be supportive for the qualitative data, the UEQ-S appeared to be a good solution to still enable a short reflective session for the participants and do not disturb the evaluation too much, especially as they have to fill out the UEQ-S three times after each think-aloud session. The short version reduces the UEQ to eight items, four representing the pragmatic quality and four for the hedonic quality of the UX. An overview of the UEQ-S is provided in Table 6.1. Each item consists of a pair of terms with opposite meanings, e.g., efficient and inefficient. Participants rate on a 7-point Likert scale how they perceive this specific item regarding the UI interaction that has just taken place.

Table 6.1.: Overview of UEQ-S items [209].

obstructive	o o o o o o o	supportive
complicated	o o o o o o o	easy
inefficient	o o o o o o o	efficient
confusing	o o o o o o o	clear
boring	o o o o o o o	exciting
not interesting	o o o o o o o	interesting
conventional	o o o o o o o	inventive
usual	o o o o o o o	leading edge

6.1.2. General Conditions and Procedure

The approvals of the University of the Bundeswehr Munich's data privacy officer and ethics committee were requested and granted to ensure a clear and correct study procedure. After receiving this approval, the acquisition of participants started with a flyer and a website sharing all relevant information about the study. Through this website, interested persons could register for the study by filling out an online survey, providing their consent for data privacy and study participation, verifying prerequisites, and submitting all relevant information for conducting the initial cultural user modeling and organizational data (name and email address) according to the first procedure step "Acquisition & Cultural User Modeling" (Subsection 5.1.1).

The prerequisites for participation were that participants must be at least 18 years old and not have any visual impairments, such as color blindness or red-green deficiency, as the color design of the UI was also relevant for the evaluation. Moreover, they must be able to speak and read either German or English, be in Munich once within the next few months (July-Sept'24), and be available for about one hour for the evaluation on-site at the campus of the University of the Bundeswehr Munich. It was estimated that the online survey takes 5–10 minutes and the on-site evaluation between 45–60 minutes.

After submitting the survey data, the users were randomly assigned to a group of six people, and their group profile was calculated by applying the two aggregation methods (average without misery and fairness), according to the second step of the procedure, "Group Modeling" (Subsection 5.1.2). The "UI Design Adaptations", step three of the procedure (Subsection 5.1.3), are identified based on these group profiles. These preferences lead to two UI versions derived and implemented for the on-site evaluation according to the fourth step of the procedure, "Group-Specific UI Implementation" (Subsection 5.1.4). After identifying these UI versions, the participants of this group were invited to select a date for their on-site evaluation session, part of the fifth step of the procedure, "Verification & Evaluation" (Subsection 5.1.5).

Each on-site evaluation began by exploring the UI versions. Participants were asked to interact with the application and express their thoughts out loud (think-aloud method). The study conductor supported these exploration phases with questions or comments that should support phrasing thoughts and focusing on the specific UI aspects of interest. After each UI version, the

UEQ-S has been submitted to the participants to recap their experience with the UI. After all three exploration phases, a semi-structured interview was conducted using previously defined questions to compare the three UI versions and the adaptations of the UI aspects in detail. The study's responsible person and an assistant were present for the on-site evaluation in most sessions. As equipment for conducting the study, it was required to have a room including a large display with touch interaction, a laptop that provided the three UI versions for evaluation, and a smartphone for video recording the think-aloud sessions with the UI versions and audio recording of the semi-structured interviews. Therefore, an SD card for the recordings was used to avoid data loss to third parties. After each session, the recordings were transmitted to a password-secured drive accessible only through the university campus network. As it was necessary to report the participants' names and IDs to show them the correct UI versions for their group, a coding table was required that matched their data to the data gathered during the study. The coding table has been deleted after conducting the on-site evaluation and transcribing their recordings. Consequently, the remaining data transcripts are anonymous and can be used for publication.

In summary, the evaluation took place for four groups, testing the personalization approach four times. Six cultural user profiles were aggregated for each group by applying two group modeling strategies (average without misery and fairness). The UI adaptations were determined and implemented for each intercultural group profile. For comparison purposes, whether the adapted UI versions improved the UX, the baseline UI has always been part of the evaluation for each participant. After determining the UI versions for the group, each participant was invited to an individual on-site evaluation session. The collected recordings were transcribed and anonymized afterward by deleting a coding table where the participants' names were documented next to their IDs. The following section provides an overview of the data collected in this study.

6.2. Data Collection

The study took place between July and October 2024, which extended the previous targeted time frame due to the summer vacation period. In total, the following data has been collected:

- **User Data:** Explicit data, implicitly derived cultural user profiles, and design preferences
- **Group Data:** Cultural user profiles that have been aggregated, group ranking of the cultural dimensions, and two intercultural group profiles (one with average without misery and one with fairness)
- **Qualitative Data:** Interview and think-aloud transcripts, actual ratings of UI versions, and actual design preferences for each user
- **Quantitative Data:** UEQ-S for each UI version and group

The most significant data volume was derived through the qualitative material and will be mainly used to derive answers. Table 6.2 provides an overview of the recorded material (audio

and video) and average values. It shows that the on-site evaluation took, on average, about 46 minutes and 36 seconds. From this total duration, the average time for the semi-structured interview was 10 minutes and 07 seconds, and for the think-aloud sessions, 36 minutes and 28 seconds. The fact that the participants took more time exploring the UI versions shows they extensively explored what they could do with the application. The interview consolidated the UI versions and their differences and was more focused on what they liked or disliked about the adaptations, which resulted in a shorter duration. The next chapter describes how the procedure is applied to the CommunityMirrors application and which data is retrieved in each step.

Table 6.2.: Overview of the recording data gathered in time (hh:mm:ss) for each participant, for each part of the evaluation, in total, and the average.

ID	Think- Aloud B	Think- Aloud V1	Think- Aloud V2	All Think- Alouds	Interview	Sum
158	00:24:39	00:13:42	00:07:28	00:45:49	00:13:46	00:59:35
159	00:12:46	00:08:14	00:02:42	00:23:42	00:09:37	00:33:19
171	00:14:29	00:10:53	00:02:10	00:27:32	00:13:53	00:41:25
173	00:19:40	00:11:30	00:04:00	00:35:10	00:06:57	00:42:07
177	00:13:33	00:06:02	00:02:13	00:21:48	00:06:26	00:28:14
181	00:15:45	00:09:53	00:05:13	00:30:51	00:07:31	00:38:22
183	00:18:38	00:08:53	00:13:40	00:41:11	00:11:33	00:52:44
188	00:09:35	00:06:34	00:05:25	00:21:34	00:06:56	00:28:30
190	00:09:57	00:06:07	00:04:53	00:20:57	00:03:52	00:24:49
211	00:25:38	00:10:44	00:15:18	00:51:40	00:07:48	00:59:28
217	00:28:02	00:03:24	00:19:31	00:50:57	00:14:28	01:05:25
218	00:19:49	00:13:16	00:06:54	00:39:59	00:06:20	00:46:19
219	00:11:21	00:04:35	00:05:30	00:21:26	00:07:16	00:28:42
232	00:09:53	00:04:53	00:11:20	00:26:06	00:11:24	00:37:30
235	00:14:49	00:10:41	00:13:12	00:38:42	00:08:53	00:47:35
244	00:22:19	00:10:58	00:14:10	00:47:27	00:12:51	01:00:18
248	00:23:39	00:08:05	00:13:06	00:44:50	00:10:20	00:55:10
250	00:16:09	00:10:23	00:13:44	00:40:16	00:10:05	00:50:21
207	00:14:58	00:08:45	00:20:29	00:44:12	00:10:40	00:54:52
254	00:11:14	00:10:49	00:10:09	00:32:12	00:12:38	00:44:50
268	00:25:43	00:19:20	00:12:22	00:57:25	00:09:54	01:07:19
288	00:09:32	00:08:01	00:17:35	00:35:08	00:07:43	00:42:51
299	00:18:49	00:10:52	00:15:11	00:44:52	00:13:49	00:58:41
298	00:12:57	00:10:38	00:07:58	00:31:33	00:18:16	00:49:49
Sum	6:43:54	3:47:12	4:04:13	14:35:19	4:02:56	18:38:15
Avg	00:16:50	00:09:28	00:10:11	00:36:28	00:10:07	00:46:36

7. Application-Specific Implementation

The application-specific implementation in this thesis provides an example of how to implement the proposed personalization approach (Chapter 5) of large interactive displays for intercultural groups in semi-public areas. Additionally, verifying and evaluating the overall approach will improve it iteratively and derive answers to open questions within the approach.

This chapter introduces the application CommunityMirrors itself (Figure 7.1), followed by an in-depth implementation example of each procedure step in the next sections. Finally, the results section will derive insights and improvements concerning the personalization approach. The application-specific implementation follows the procedure and uses the ontologies for a general understanding. The system architecture is transferred to an application-specific one and is displayed in Figure 7.4.



Figure 7.1.: CommunityMirror deployed at a corridor in University of the Bundeswehr Munich.

7.1. CommunityMirrors

The application used to verify and evaluate the personalization approach of intercultural adaptation of large interactive displays is CommunityMirrors [110]. The CommunityMirrors *mirror* the current community members and activities by displaying hidden information from information systems, in this case, publication databases, on large interactive displays in semi-public areas, also called out-of-the-box, to foster knowledge sharing and connections within the community. In detail, the large interactive display shows various content that may be interesting for the community, following the serendipity principle [25, 73, 194]. This content is information about the community members (people from the Computer Science department), information about the community (organization, University of the Bundeswehr Munich in general, and other departments), and information about the members' activities and related topics (content, including publications, projects, events, open thesis topics, etc.).

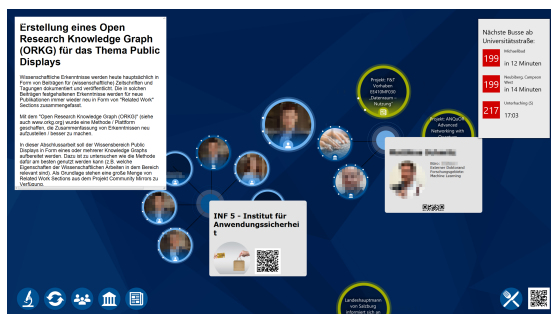


Figure 7.2.: Baseline UI with a teaser (left), an organizational and a person particle in DetailView, including network graph.



Figure 7.3.: Baseline UI with FlowView example and a panel overview, triggered by the person button.

These CommunityMirrors are located in four different areas within the university; an example is displayed in Figure 7.1, which shows such a CommunityMirror in a corridor. In these areas, we encounter intercultural situations in front of the display as the user groups are culturally diverse. Examples of the UI used in further analysis as **baseline UI**, which is the current UI version, are provided in Figure 7.2 and Figure 7.3. Relevant UI elements and characteristics of the CommunityMirror are the following:

- **(Information)particles:** The information particles are the circles or information objects that display all content available for the CommunityMirrors and move across the screen from left and right. This includes particles about the people, the organization, and the news (in Figure 7.2 and Figure 7.3 light blue is person, green is content, and dark blue are organizational particles). Most particles contain a picture, a headline (name or title), and a detailed description, which differs depending on the content type.
- **FlowView:** The FlowView is the main view where a certain amount of information particles flows randomly from left to right, and vice versa, in various sizes, allowing multi-user interaction from near and far.

- **DetailView:** The DetailView appears after selecting a particle, e.g., from FlowView, as a small window and contains more details about that specific particle and displays the connected particles in a network graph.
- **Network graph:** The network graph is displayed surrounding the particles in DetailView (Figure 7.2, Figure 7.3) and shows connected particles to that specific one, e.g., clicking on a person, the corresponding department (organization), and publications (content) are shown. Users can click on the connected particles displayed from the network graph if interested. There is a maximum of eight particles in the network graph, which means that if more particles than eight are connected to this one, they will be randomly selected and always show different ones.
- **Teaser:** The teaser (Figure 7.2, left side) appears randomly and puts a particular content in focus with its position and size. This content includes events, posters, open thesis topics, and others from the particle type “content”.
- **Sticky components:** These UI elements are static and do not change their position. These are the clock (upper left corner), bus schedule (upper right corner), and the buttons on the bottom part of the UI. These buttons are, from left to right, a microscope (enables switching through teaser component), refresh button (to restart the FlowView and get other particles), person button (displays a panel as an overview of all current Professors or employees near the display), mensa (shows the weekly menu of the mensa), QR-code (opens a short description of the project).
- **Panels:** The panel (Figure 7.3, center), which is currently implemented, is triggered by clicking on the person button. It shows an overview of all current Professors or employees, depending on the CommunityMirrors location.

Choosing CommunityMirrors as the application for implementing the proposed personalization approach offers several advantages. As a member of the development and maintenance team, the author has full access to the application’s source code and configurations, enabling a highly flexible and adjustable research environment. Additionally, the long-term deployment of such systems has provided the team with in-depth expertise regarding the technical and practical challenges associated with these displays. This extensive knowledge supports precise adjustments, refinements, and the practical realization of the personalization potential for intercultural design preferences in such contexts.

7.2. System Architecture for CommunityMirrors

For the application-specific implementation of the personalization approach, the general system architecture (Section 5.3) has been adjusted to suit the CommunityMirror application. The system architecture transferred for CommunityMirrors (Figure 7.4) incorporates information about the technologies used within this implementation.

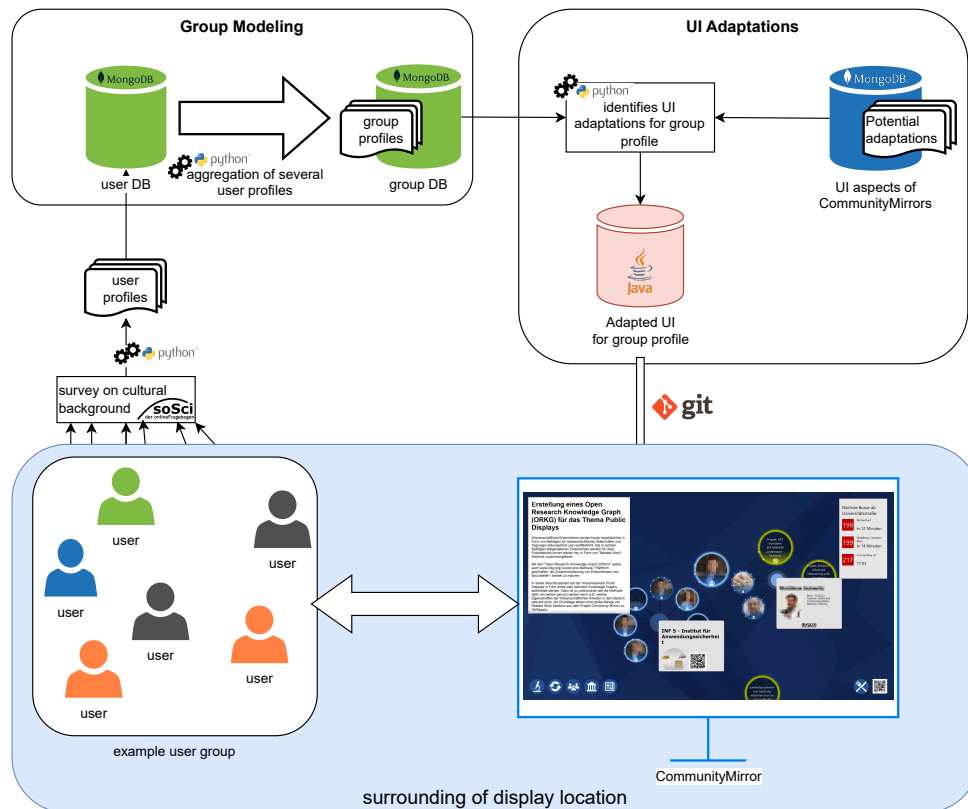


Figure 7.4.: System architecture for the application-specific implementation of the personalization approach for CommunityMirrors.

In this case, the large interactive display is an instance of the CommunityMirror. The user groups are supposed to consume and interact with the CommunityMirror, which comprises six employees in its surroundings. In this evaluation, these participants were randomly assigned to a group. The users submit information about their cultural background using the soSci survey tool¹. Using a Python script, the information provided by the users is transformed into cultural user profiles with values for all cultural dimensions of Hofstede. These are then stored in a database. The group modeling of six cultural user profiles, including ranking cultural dimensions and aggregation using the two strategies, average without misery and fairness, was conducted using a Python script. The determined intercultural group profiles were then also stored in a database. The UI adaptations for CommunityMirror were stored in an adaptation table. Matching this table with the group profile identifies the group's UI design preferences. By comparing these with the current UI version, UI adaptations can be revealed. These adaptations were implemented for a CommunityMirror, a Java-based application, using visualizations through JavaFX. In a fully automated deployment, a scalable database solution that supports real-time access and efficient data management would store user and group profiles and UI adaptations.

¹<https://survey.unibw.de>

A document-based database such as MongoDB² would be well-suited for this purpose as it allows flexible schema evolution and efficient querying for personalization. However, a simplified approach was chosen for the laboratory-based evaluation: user and group profiles were stored in CSV files, such as the adaptation table. This decision was made to facilitate manual inspection and ease of data handling within the experimental setting, where full automation was not required. The conceptual architecture remains unchanged, and transitioning from CSV-based storage to a database system such as MongoDB would be straightforward in real-world field deployments.

7.3. Acquisition & Cultural User Modeling

The first step of the procedure covers acquiring user information essential to deriving a cultural user profile. The first part is identifying the users in the vicinity of the display. To avoid bias due to personal relationships with the current deployments of the displays and, consequently, the personally well-known users in their surroundings, the users for the evaluation were recruited mainly outside of the current environment to obtain more neutral feedback. The recruitment procedure of such participants is already described in Subsection 6.1.2. Each registered participant submitted the required information via a survey. Based on this data, the cultural user profiles were determined. The following parts summarize the data for each group, including aggregated submitted data, due to data privacy concerns, and determined user profiles.

Data of Group 1 This part aggregates the online survey data submitted by participants in group 1. Using this user data, the cultural user profile has been implicitly derived by applying the cultural user modeling procedure described in the approach, Subsection 5.1.1. The identified cultural user profiles for group 1 are displayed in Table 7.1. Due to data privacy, only aggregated data is shown for the whole group to determine the anonymity of the study data in total:

- **Participant IDs:** 158, 159, 171, 173, 177, 181
- **Gender:** 4 female, 2 male
- **Average age:** 39,33
- **1st nationalities:** German, Croatian, Italian
- **Nationalities of parents:** Chinese, German, Croatian, Italian
- **Current residence & duration:** Germany (4 x always, 1 x for 167 months, 1 x for 67 months)
- **Previous residences & duration (in months):** China (336), Australia (12), Chile (5), Croatia (1), Spain (2), Italy (399)
- **Political orientation:** 1 x *more right*, 2 x *more middle*, 2 x *more left*, 1 x *none*.

²<https://www.mongodb.com/>

Table 7.1.: Cultural user profiles for each participant of group 1.

ID	PD	IDV	MAS	UA	LTO	IND
158	61	70	66	45	68	31
159	35	79	66	65	57	40
171	35	63	66	65	57	41
173	35	63	66	65	57	40
177	54	61	53	72	49	37
181	47	57	69	73	42	32

Data of Group 2 This part aggregates the online survey data submitted by participants in group 2. Using this user data, the cultural user profile has been implicitly derived by applying the cultural user modeling procedure described in the approach, Subsection 5.1.1. The identified cultural user profiles for group 2 are displayed in Table 7.2. Due to data privacy, only aggregated data is displayed for the whole group to determine the anonymity of the study data in total:

- **Participant IDs:** 183, 188, 190, 211, 217, 218
- **Gender:** 3 female, 2 male, 1 divers
- **Average age:** 40,³³
- **1st nationalities:** German, Belarusian, Croatian, Iranian
- **Nationalities of parents:** German, Belarusian, Croatian, Iranian
- **Current residence & duration:** Germany (3 x always, 1 x for 58 months, 1 x for 42 months, 1 x for 75 months), Austria (1 x for 42 months)
- **Previous residences & duration (in months):** USA (2), Belarus (218), Croatia (330), Iran (297)
- **Political orientation:** 2 x *more middle*, 2 x *more left*, 2 x *none*.

Table 7.2.: Cultural user profiles for each participant of group 2.

ID	PD	IDV	MAS	UA	LTO	IND
183	35	79	66	65	57	40
188	89	41	25	92	53	18
190	69	44	42	79	40	35
211	35	79	66	65	57	40
217	35	63	66	65	57	40
218	56	29	45	60	33	40

Data of Group 3 This part aggregates the online survey data submitted by participants in group 3. Using this user data, the cultural user profile has been implicitly derived by applying the cultural user modeling procedure described in the approach, Subsection 5.1.1. The identified cultural user profiles for group 3 are displayed in Table 7.3. Due to data privacy, only aggregated data is displayed for the whole group to determine the anonymity of the study data in total:

- **Participant IDs:** 219, 232, 235, 244, 248, 250
- **Gender:** 1 female, 5 male
- **Average age:** 34,³³
- **1st nationalities:** Uruguayan, German, Indian
- **2nd nationalities:** German
- **Nationalities of parents:** Uruguayan, German, Spanish, Indian
- **Current residence & duration:** Germany (3 x always, 1 x for 372 months, 1 x for 43 months, 1 x for 44 months)
- **Previous residences & duration (in months):** UK (1), USA (108/7), France (12), Finnland (1), Sweden (1), Indian (279/268)
- **Political orientation:** 4 x *more middle*, 2 x *none*.

Table 7.3.: Cultural user profiles for each participant of group 3.

ID	PD	IDV	MAS	UA	LTO	IND
219	42	74	58	74	50	43
232	36	76	65	62	56	44
235	74	28	57	42	51	27
244	35	79	66	65	57	40
248	74	28	57	42	51	27
250	35	79	66	65	57	40

Table 7.4.: Cultural user profiles for each participant of group 4.

ID	PD	IDV	MAS	UA	LTO	IND
207	26	66	57	58	53	36
254	58	40	57	79	29	63
268	35	78	66	64	57	41
288	35	63	66	65	57	40
299	76	25	56	40	51	26
298	54	55	44	83	48	44

Data of Group 4 This part aggregates the online survey data submitted by participants in group 4. Using this user data, the cultural user profile has been implicitly derived by applying the cultural user modeling procedure described in the approach, Subsection 5.1.1. The identified cultural user profiles for group 4 are displayed in Table 7.4. Due to data privacy, only aggregated data is displayed for the whole group to determine the anonymity of the study data in total:

- **Participant IDs:** 207, 254, 268, 288, 299, 298
- **Gender:** 4 female, 2 male
- **Average age:** 39,16
- **1st nationalities:** Israeli, Columbian, German, Indian, Spanish
- **2nd nationalities:** British, Spanish
- **Nationalities of parents:** Israeli, British, Columbian, German, Spanish, Indian
- **Current residence & duration:** Germany (2 x always, 1 x for 63 months, 1 x for 132 months, 1 x for 11 months, 1 x for 108)
- **Previous residences & duration (in months):** UK (234,5), Israel (223), Turkey (6), Botswana (24), Spain (54/368), Taiwan (3), Columbia (180), Ireland (24), India (349), Netherlands (11), Finland (5)
- **Political orientation:** 2 x *more middle*, 3 x *more left*, 1 x *none*.

7.4. Group Modeling

Based on the identified cultural user profiles for all 24 participants, the next step is conducting the group modeling as described in Subsection 5.1.2. It covers the calculation of the group profiles using the two aggregation strategies to be verified, average without misery and fairness, and shows the ranking results for all groups.

7.4.1. Extent of Cultural User Profiles

For some group modeling calculations, it is necessary to identify the values' relevance by differentiating the extent of the dimension values from one another. Therefore, the difference of each cultural value from 50, the middle of possible values, has been calculated (Equation (5.12)) and used in some of the further computational steps. As an overview, the cultural user profiles and their relevances are displayed in Table 7.5 for all participants.

Table 7.5.: Cultural user profiles for all participants and their values for each cultural dimension and *relevance of the cultural dimensions (Equation (5.12)).

Group	ID	PD	IDV	MAS	UA	LTO	IND	PD*	IDV*	MAS*	UA*	LTO*	IND*
1	158	61	70	66	45	68	31	+11	+20	+16	-5	+18	-19
1	159	35	79	66	65	57	40	-15	+29	+16	+15	+7	-10
1	171	35	63	66	65	57	41	-15	+13	+16	+15	+7	-9
1	173	35	63	66	65	57	40	-15	+13	+16	+15	+7	-10
1	177	54	61	53	72	49	37	+4	+11	+3	+22	-1	-13
1	181	47	57	69	73	42	32	-3	+7	+19	+23	-8	-18
2	183	35	79	66	65	57	40	-15	+29	+16	+15	+7	-10
2	188	89	41	25	92	53	18	+39	-9	-25	+42	+3	-32
2	190	69	44	42	79	40	35	+19	-6	-8	+29	-10	-15
2	211	35	79	66	65	57	40	-15	+29	+16	+15	+7	-10
2	217	35	63	66	65	57	40	-15	+13	+16	+15	+7	-10
2	218	56	29	45	60	33	40	+6	-21	-5	+10	-17	-10
3	219	42	74	58	74	50	43	-8	+24	+8	+24	0	-7
3	232	36	76	65	62	56	44	-14	+26	+15	+12	+6	-6
3	235	74	28	57	42	51	27	+24	-22	+7	-8	+1	-23
3	244	35	79	66	65	57	40	-15	+29	+16	+15	+7	-10
3	248	74	28	57	42	51	27	+24	-22	+7	-8	+1	-23
3	250	35	79	66	65	57	40	-15	+29	+16	+15	+7	-10
4	207	26	66	57	58	53	36	-24	+16	+7	+8	+3	-14
4	254	58	40	57	79	29	63	+8	-10	+7	+29	-21	+13
4	268	35	78	66	64	57	41	-15	+28	+16	+14	+7	-9
4	288	35	63	66	65	57	40	-15	+13	+16	+15	+7	-10
4	299	76	25	56	40	51	26	+26	-25	+6	-10	+1	-24
4	298	54	55	44	83	48	44	+4	+5	-6	+33	-2	-6

Table 7.6.: Ranking result by applying Borda count to the user profiles for each group.

Group	1. Place	2. Place	3. Place	4. Place	5. Place	6. Place
1	LTO	PD	IND	IDV	UA	MAS
2	UA	IDV	PD	MAS	IND	LTO
3	IDV	PD	MAS	UA	IND	LTO
4	UA	IDV	PD	MAS/IND		LTO

7.4.2. Ranking by Borda Count

In some cases, UI aspects are not uniquely assigned to one cultural dimension as they are connected to several cultural dimensions. Consequently, it is necessary to rank the importance of each cultural dimension for the group to decide which cultural dimension is more pronounced and which UI preferences are more prevailing.

The Borda count method is suitable for ranking cultural dimensions (Subsection 5.1.2). Table 7.6 presents the result of applying the Borda count to the user values, deriving the overall ranking for their groups. Unfortunately, the Python script used in the beginning to automate this calculation was incorrect, which led to a calculation mistake for the ranking of group 1, resulting in an inverted ranking. Despite this, the adaptations selected based on this incorrect ranking still align with the group's preferences as they correspond to the group's intercultural profile identified with the aggregation. Since the ranking is not the focus of this evaluation and it serves only to decide on the adaptation for three UI aspects out of six, the group was retained in the analysis as the chosen adaptations remain valid because they are chosen based on the group's profiles.

7.4.3. Average without Misery

The first approach applied was to calculate the group profile using the average without misery strategy (for more details, see section 5.1.2). Therefore, the threshold was carefully selected at 10 (excluding values ± 10 from 50) to ensure that most values are still considered and to filter out values not strongly pronounced in the medium range. This means that all values between 40 and 60 were ignored when calculating the average for the group.

The result for each group is displayed in Table 7.7, while only values considered are reported in this table. For group 3, the LTO value has been set to 50. This was selected because, due to the threshold, no values were left for the calculation, which means that all participants are in the span of 40 to 60. The aggregation result for each cultural dimension and group is further interpreted according to the adaptation degrees (low (<34), medium (34–67), high (>67)).

7.4.4. Fairness

The second approach calculated the group profile using the fairness strategy. For this method, the most pronounced value, the highest absolute number from the table with the differences from 50, was subsequently selected for each group member. The order was randomized by their order within their appearance in the group and not influenced by other factors. This approach assumes that with this strategy, everyone will receive at least one value matching their preferences.

Sometimes, the most pronounced value is close to another very high value, e.g., 78 in UA and 74 in IDV. Assuming that both values would be almost equally strong and, thus, similarly important to that user, selecting a slightly lower value than the most pronounced one by that user may cause less harm to others. These differences, the damage to others, have been considered in the calculation for all values within the range of -5 of the highest available value of that user (for more details, see section 5.1.2).

Table 7.7.: Group profiles and considered values of user profiles when applying the average without misery strategy with a threshold of 10.

Group	ID	PD	IDV	MAS	UA	LTO	IND
1	158	61	70	66		68	31
1	159	35	79	66	65		
1	171	35	63	66	65		
1	173	35	63	66	65		
1	177		61		72		37
1	181			69	73		32
1	value	41.50	67.20	66.60	68.00	68.00	33.33
1	degree	medium	high	medium	high	high	low
2	183	35	79	66	65		
2	188	89		25	92		18
2	190	69			79		35
2	211	35	79	66	65		
2	217	35	63	66	65		
2	218		29			33	
2	value	52.60	62.50	55.75	73.20	33.00	26.50
2	degree	medium	medium	medium	high	low	low
3	219		74		74		
3	232	36	76	65	62		
3	235	74	28				27
3	244	35	79	66	65		
3	248	74	28				27
3	250	35	79	66	65		
3	value	50.80	60.67	65.67	66.50	NaN (50)	27.00
3	degree	medium	medium	medium	medium	medium	low
4	207	26	66				36
4	254				79	29	63
4	268	35	78	66	64		
4	288	35	63	66	65		
4	299	76	25				26
4	298				83		
4	value	43.00	58.00	66.00	72.75	29.00	41.67
4	degree	medium	medium	medium	high	low	medium

Table 7.8 presents the result for each group, showing the selected value for each participant in sequence to clarify how the final values were determined. The asterisk marks values chosen due to lower damage in case of equal or close values (within a range of 5). This result can be interpreted based on the adaptation degrees: low (<34), medium (34–67), high(>67).

Table 7.8.: Group profiles and selected values of each user when applying the fairness strategy, *values that are chosen due to less damage for other users.

Group	ID	PD	IDV	MAS	UA	LTO	IND
1	158			66*			
1	159		79				
1	171				65*		
1	173	35					
1	177						37
1	181					42	
1	value	35	79	66	65	42	37
1	degree	medium	high	medium	medium	medium	medium
2	183		79				
2	188				92		
2	190	69					
2	211			66			
2	217						40
2	218					33	
2	value	69	79	66	92	33	40
2	degree	high	high	medium	high	low	medium
3	219		74*				
3	232			65			
3	235						27*
3	244				65*		
3	248	74					
3	250					57	
3	value	74	74	65	65	57	27
3	degree	high	high	medium	medium	medium	low
4	207	26					
4	254				79		
4	268		78				
4	288			66			
4	299						26
4	298					48	
4	value	26	78	66	79	48	26
4	degree	low	high	medium	high	medium	low

Table 7.9.: Comparison of group modeling result by value and adaptation degree. Abbreviations: fai = fairness, avg w/o mis. = average without misery, + signals a difference in degree, / no difference.

Group	Method	PD	IDV	MAS	UA	LTO	IND
1	avg w/o mis.	41.50	67.20	66.60	68.00	68.00	33.33
1	fai	35	79	66	65	42	37
1	degree avg w/o mis.	medium	high	medium	high	high	low
1	degree fai	medium	high	medium	medium	medium	medium
1	difference	/	/	/	+	+	+
2	avg w/o mis.	52.60	62.50	55.75	73.20	33.00	26.50
2	fai	69	79	66	92	33	40
2	degree avg w/o mis.	medium	medium	medium	high	low	low
2	degree fai	high	high	medium	high	low	medium
2	difference	+	+	/	/	/	+
3	avg w/o mis.	50.80	60.67	65.67	66.50	NaN (50)	27.00
3	fai	74	74	65	65	57	27
3	degree avg w/o mis.	medium	medium	medium	medium	medium	low
3	degree fai	high	high	medium	medium	medium	low
3	difference	+	+	/	/	/	/
4	avg w/o mis.	43.00	58.00	66.00	72.75	29.00	41.67
4	fai	26	78	66	79	48	26
4	degree avg w/o mis.	medium	medium	medium	high	low	medium
4	degree fai	low	high	medium	high	medium	low
4	difference	+	+	/	/	+	+

7.4.5. Comparison of Group Modeling Strategies

This part provides an overview of the identified differences by applying the average without misery and fairness strategy for group modeling. Therefore, the final results, the values, and the interpreted adaptation degrees are compared in Table 7.9. It shows that applying these two strategies results in different group profiles. The question remains: Which group profile represents intercultural group preferences more successfully? Based on these intercultural group profiles, the UI versions for each profile are derived.

7.5. Identification of User Interface Adaptations

This section determines application-specific adaptation rules and UI design preferences for each group based on their intercultural group profiles. Therefore, it is necessary first to interpret the general adaptation rules for the CommunityMirror application. Consequently, the transfer of the

general adaptation rules to the CommunityMirror application is described in detail. Thereafter, the previously derived group profiles are matched with the CommunityMirror adaptation rules to identify CommunityMirror-related design preferences for each group.

7.5.1. CommunityMirror Adaptation Rules

To demonstrate and test the adaptation of a large interactive display to the intercultural design preferences of a group, the general adaptation rules table from the previous chapter (Table 4.3) was concretized with the help of an expert workshop. The objective was to substantiate what represents the UI aspects in the CommunityMirror application, identify the current degree (low, medium, high), and derive changes for other adaptation degrees. While the general cultural adaptation rules only distinguish between high and low, as Hofstede's cultural dimensions are usually interpreted as below 50 being low and above 50 being high, this approach aims at a more diverse differentiation using low, medium, and high categories. This should enable a better preference distinction. Five experts gathered for two hours and discussed the following questions, also summarized in Subsection 5.1.3:

1. What are the culturally relevant UI aspects within the CommunityMirror application?
2. How can the current UI design be classified regarding the adaptation degrees: low, medium, and high?
3. What changes are required to achieve other adaptation degrees?

CommunityMirror UI Aspects

Most of the time of the expert workshop was spent on discussing different understandings of the UI aspects and agreeing on specific elements or criteria that are relevant to them. Finally, the six UI aspects were defined as follows for the CommunityMirrors:

- **Functionalities:** Usually, in classic web applications, functionalities cover editing, creating, or deleting content. However, for CommunityMirrors, the discussion showed that the use case of this application should not support editing content because the primary purpose is to show information about people, organizations, and what they are working on (read-only) and no real-time editing of content using the semi-public display. Moreover, the information displayed relies on validity and contains partly confidential data (personal data about employees and departments). Consequently, functionalities, in this case, are more about the ability to **control what information** is displayed, how the user can explore the content, and what possibilities are provided to access them. Consequently, the current functions are represented mainly by the buttons: The buttons in the left bottom corner (microscope puts content in focus as teasers, refresh restarts the FlowView, the people button enables an overview of the employees as a panel) and on the right bottom corner (the fork and knife button enables opening the weekly mensa menu, the QR-code displays an explanation of the display itself).

- **Level of detail:** One way of interpreting this UI aspect can be to focus on the steps required to receive a certain amount of detailed information: How many **interaction steps**, touches in our case, does the user need to explore more? Currently, the particles for a person, for instance, show a name and a picture in the FlowView. After clicking on that particle, the DetailView is presented, which shows all relevant information about the person and the surrounding network graph that allows browsing through related content, e.g., publications, the department, etc. In this case, one click is required to receive all information about one item.
- **Density:** While other work assumes that density and the level of detail are influencing each other and are therefore not differentiated strongly [186, p. 95][139], these aspects are more clearly distinguished within the CommunityMirror application. Thus, the density is described as the **number of particles** shown on the UI and the percentage of how much of the background is covered. Of course, if the level of detail, for example, leads to larger particles as more details are provided at first sight, this also impacts the coverage of the overall background and needs to be considered.
- **Content type:** The overall content type within the CommunityMirrors focuses so far mainly on **formal content**, which is heavily **person-related**: Persons, organizations, and content including newsfeed (mostly related to a person in this department). As informal content, **memes** are currently included, which are not person-related.
- **Colorfulness:** As colorfulness, the amount and contrasts of colors used are discussed for the application. The overall color scheme of the CommunityMirrors is **blue-green** due to an event that took place at a company with these corporate design colors (blue and a bit of green). However, they do not currently match the colors of the University of the Bundeswehr Munich, where the displays are deployed. The **background** is blue with a geometric pattern. The following colors differentiate the content types: persons are light blue, organizations are dark blue, and content (news) particles are green. The colors are static, and no animations are implemented.
- **Informativeness of colors:** The informativeness of colors is defined in this application by whether a user can identify a color's meaning within a short interaction period. This covers the differentiation between the three content types (person, organization, content) and the overall color meaning (if there is one). Also, repetitive usage of colors is a factor influencing this UI aspect.

Classification of the Current UI

The current degree for each UI aspect must be classified to derive the necessary UI adaptations. Each expert was allowed to rate the six UI aspects as low, medium, or high, if applicable. The result shows the rating and result for the classification of the baseline UI that serves as a basis for comparing various adaptation degrees.

- **Functionalities:** All experts agreed on a **medium** degree as currently some functions are available to explore the content displayed, e.g., skipping through “teasers” with the microscope button, getting an employee overview with the person button, etc. However, these functions could easily be reduced or expanded.
- **Level of detail:** Three out of five experts voted clearly for medium, and two voted for low. In this case, the current visualization is slightly adjusted to make it clear at a **medium** level by adding the content type icon (person, organization, or content) to the particle in FlowView referring to the content type, e.g., the news received the document icon, organizational particles the institution icon, person particles the person icon.
- **Density:** The majority, three out of five, voted for low, while two voted for medium. The two experts who voted for medium could be shifted towards **low** by slightly reducing the number of particles. This number changes with display size and the level of detail, so it can not be a fixed value.
- **Content type:** All experts rated the content as **formal**, mainly focusing on individuals, groups, and organization content. For the baseline UI, the memes will be removed to avoid mixtures.
- **Colorfulness:** While three out of five rated the current design as monotonously colored (low), two experts rated it as medium colorfulness. To better distinguish adaptations for this UI aspect, the experts agreed to keep this version as **medium** colorful and define the low colorfulness by, for example, changing the color for “content” particles to another shade of blue, consequently eliminating green from the color scheme.
- **Informativeness of colors:** This element raised a lot of discussions; three experts did not think that any meaning behind the colors could be identified in a short interaction period, while two experts rated it as medium informativeness. Focusing on the definition of informativeness of colors in our case, e.g., the meaning of colors needs to be evident within a short interaction time, the current design is **low** (no informative purpose) as a long or recurring interaction is required to be able to differentiate the content by colors.

The next step is to identify various adaptations for other degrees suitable for these six UI aspects within the CommunityMirror application.

Adaptation Degrees for UI Aspects

Other versions of the UI aspects were discussed during the expert workshop. To enable some adaptations and create synergies between them, some elements have been implemented and already changed in the baseline UI, in contrast to the operated field deployment. Two more buttons on the bottom left side will represent the other content types: organization (symbolized by a house) and content (symbolized by a newspaper). Furthermore, icons for each content type will be displayed in the particles in FlowView, and the DetailView will be designed more aesthetically.

In addition, the other adaptation degrees are:

- **Functionalities:** The buttons will be adjusted for the UI aspect functionalities by removing or adding additional buttons. For example, removing the microscope, refresh, and QR code buttons will lower functionality, while enabling new organizational and content overview panels will increase functionality.
- **Level of detail:** The steps required to receive all relevant information will be adapted to adjust the level of detail. To achieve a lower level of detail, the person's and organizational names will be removed from FlowView, and a button will be implemented to separate and hide parts of the content in DetailView. For a higher level of detail, the particles in FlowView will be enhanced by showing already basic information from the DetailView, thus reducing touch interactions. With this step, it is necessary to consider the space each particle occupies, which impacts the UI aspect density.
- **Density:** Density will be adapted based on the number of particles. Therefore, the number will be increased for medium and high density.
- **Content type:** Regarding the content type, there are other adaptation degrees than low and high. The baseline UI applies mainly formal content with a balanced amount of person particles and other work-related content. Informal content, memes, and information about social activities, e.g., the department's next bike tour, will be included for other adaptation degrees. Furthermore, another degree of adaptation would be to focus more on products. In the context of CommunityMirrors, these products are research outcomes and content particles, which will be focused on in this adaptation degree by increasing the number of these content types.
- **Colorfulness:** For colorfulness, a more reduced version is achieved by removing the green color and moving entirely to a blue color scheme. In contrast, high colorfulness will be implemented by using additional colors with increased contrast to differentiate the content types even better.
- **Informativeness of colors:** Finally, the informativeness of colors is influenced by the UI aspect of colorfulness. Currently, the degree is rated as low in informativeness. To increase this UI aspect to medium, the buttons for person, organization, and content on the bottom left corner will be colored by type, providing a legend for the colors. However, if the colorfulness is supposed to be low, the overall colors used will be transferred to the corporate design of the University of the Bundeswehr Munich, an orange-gray color scheme, which provides more meaning as color-encoded information, showing that this UI belongs to this university. For the adaptation degree of high informativeness of colors, the DetailView will receive a background color corresponding to the particle type color as redundant color-encoded information.

As a result, the adaptation degrees of low, medium, and high (3) and the now seven UI aspects with their respective adaptations (as the UI aspect informativeness of colors could be separated into two different versions, one for low colorfulness and one for at least medium colorfulness) lead to 3^7 , **2.187** design possibilities. This high number justifies the objective to make such a UI as adaptive as possible. An overview of the adaptation degrees for the CommunityMirror is summarized in Table 7.10, where the symbol # marks the current classification. Examples of other adaptation degrees and how they have been implemented are displayed in Figure 7.5, which provides exemplary UI versions and adaptation degrees to underpin the adaptation effect on the UI of CommunityMirrors.

Table 7.10.: Application-specific low, medium, and high adaptation degrees for the six culturally relevant UI aspects. The # marks the current deployment, and the + shows that these rules need to be applied as well for higher adaptation.

UI Aspect	Low/Formal	Medium/Formal Only	High/Informal
Functionalities	Fl : remove buttons (microscope, refresh, QR-code)	Fm +#	Fh : add panels for organization and content button
Level of detail	LI1 : remove names from person and organization particles in FlowView LI2 : separate information in DetailView (button)	Lm +#	Lh : show [part of] DetailView directly in FlowView
Density	DI #	Dm : increase number of particles by 1.5	Dh : increase number of particles by 2
Content type	Tf1 : formal #	Tf2 : formal only, increase content particles	Ti : informal, social activities, memes
Colorfulness	Cl : remove green, switch to corporate design (if Im/Ih)	Cm +#	Ch : use more diverse colors
Informativeness	Ii #	Im1 : legend by coloring the buttons+ Im2 : corporate design+	Ih : color background of DetailView in particle type color

7.5. Identification of User Interface Adaptations

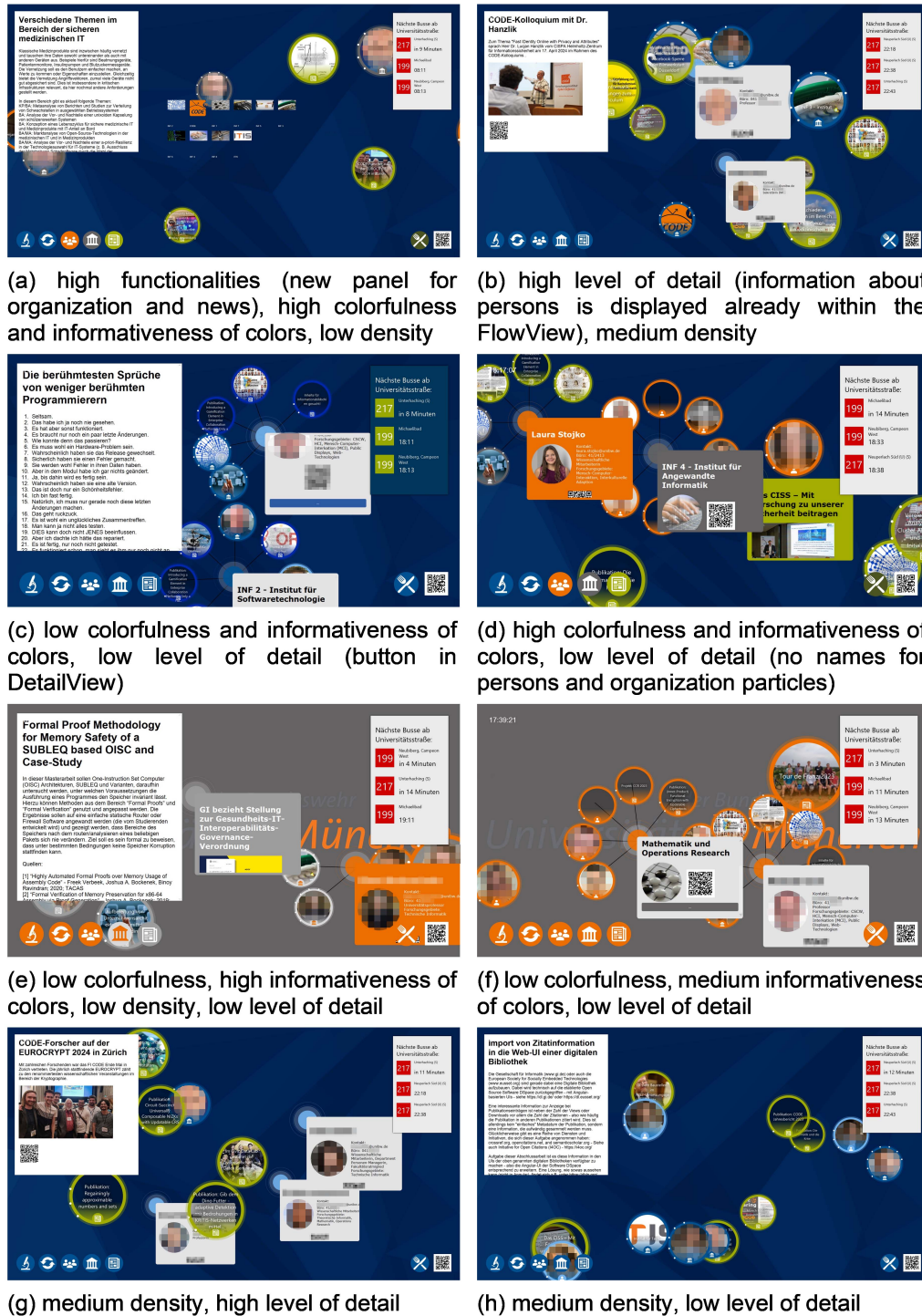


Figure 7.5.: Screenshot of various implemented adaptations for diverse UI aspects degrees.

Adaptation Table For CommunityMirrors

Building upon the results of the expert workshop, the different adaptations for each UI aspect can be transferred into an adaptation table for the CommunityMirrors, summarized in Table 7.11. The # marks the current degree for each UI aspect and displays the baseline UI. This result shows how general adaptation rules can be transferred to an application. Based on these adaptation rules, UI design preferences concerning the CommunityMirrors can be identified. An essential part of identifying the specific adaptation examples was considering relations and dependencies, e.g., low colorfulness but high informativeness of colors. However, changing too many parts of the UI for a specific UI aspect would blur the adaptation's effect. Consequently, criteria and elements relevant to each UI aspect were defined through extensive discussion, which will be used to evaluate participants' feedback regarding the UI aspects and their adaptation degrees.

Table 7.11.: Adaptation rules for CommunityMirrors for each cultural dimension's low, medium, or high value. Abbreviations: See details in Table 7.10, CD = cultural dimension, # = current deployment.

CD	Degree	UI Aspects					
		Function- nalities	Level of Detail	Density	Content Type	Colorful- ness	Informativ- ness
PD	low	Fh	Lh		Tf1 #		
	medium	Fm #	Lm #		Tf1 + Ti		
	high	FI	LI		Ti		
IDV	low				Tf2	Ch	II #
	medium				Tf2	Cm #	Im1 [if Cm ∨ Ch] Im2 [if CI]
	high				Tf1 #	CI	Ih
UA	low		Lh				II #
	medium		Lm #				Im1 [if Cm ∨ Ch] Im2 [if CI]
	high		LI				Ih
LTO	low			DI #			
	medium			Dm			
	high			Dh			
IND	low				Tf1 #		
	medium				Tf1 + Ti		
	high				Ti		

7.5.2. Group-Specific User Interface Adaptations

The determined group profiles are now matched to the adaptation table (Table 7.11), which includes a degree for each UI aspect and the preference that is assumed depending on the intercultural group profile. This leads to two different UI versions: Version 1 as the result for the group profile calculated with average without misery, and version 2 as the result for the group profile calculated with fairness. An overview of the group's design preferences (Table 7.12) shows whether the baseline UI is appropriate in this specific aspect, marked by an asterisk, or should be adapted according to the group profile, resulting in required UI adaptations. Of course, the previously determined ranking for each group has also been considered when identifying the UI adaptations for the level of detail, content type, and informativeness of colors. As an example, the identification of adaptations for group 3 is explained in the following summary:

- **Functionalities:** The degree of the cultural dimension PD is relevant for this UI aspect. For group 3, the degrees medium (average without misery) and high (fairness) have been identified, which leads to the adaptations of medium (version 1, average without misery) and low (version 2, fairness).
- **Level of detail:** This UI aspect is related to the cultural dimensions PD and UA. This group's ranking shows that PD is higher than UA, which means that a medium PD for the first version and a high PD for the second version need to be considered. This can be further interpreted as a medium degree for version 1 (average without misery), the same as the baseline UI; therefore, no changes will occur, and a lower level of detail for version 2 (fairness).
- **Density:** The cultural dimension LTO relates to this UI aspect. Both group profiles have a medium value in this dimension, leading to a medium density.
- **Content type:** As this UI aspect is linked with three cultural dimensions, PD, IDV, and IND, the ranking shows that the values of IDV should be used for this UI aspect. The IDV values for group 3 are medium (average without misery) and high (fairness), which results in a mainly formal content version 1 (average without misery) and a formal version as already implemented in the baseline UI (version 2, fairness).
- **Colorfulness:** The IDV value is relevant for this UI aspect, which is medium (average without misery) and high (fairness) for this group. As a result, the colorfulness is kept medium in version 1 (average without misery) and decreased to low for version 2 (fairness).
- **Informativeness of colors:** This UI aspect is linked to the IDV and UA dimensions. The ranking shows that the adaptations related to IDV are relevant in this case. Again, the informativeness should be adapted to medium for version 1 (average without misery) and high for version 2 (fairness).

Table 7.12.: UI adaptations refer to all preferences identified per group profile for each UI aspect without an asterisk. Abbreviations: fai = fairness, avg w/o mis. = average without misery, *same as in baseline UI.

Group	Version	Functionalities	Level of Detail	Density	Content Type	Colorfulness	Informativeness
1	1 (avg w/o mis.)	medium*	medium*	high	formal + informal	low	high
1	2 (fai)	medium*	medium*	medium	formal + informal	low	high
2	1 (avg w/o mis.)	medium*	low	low*	formal only	medium*	high
2	2 (fai)	low	low	low*	formal*	low	high
3	1 (avg w/o mis.)	medium*	medium*	medium	formal only	medium*	medium
3	2 (fai)	low	low	medium	formal*	low	high
4	1 (avg w/o mis.)	medium*	low	low*	formal only	medium*	high
4	2 (fai)	high	low	medium	formal*	low	high

7.6. Group-Specific User Interface Implementation

Based on the previously derived UI adaptations, the baseline UI was modified to match each group's design preferences, resulting in two adapted versions per group. Example screenshots and key characteristics of each version are presented below.

Group 1 – Version 1 The first adapted UI version of group 1 was implemented with a high density of particles in FlowView, which can be observed in Figure 7.6. Moreover, social activities as informal content are included as particles in the FlowView, visible in this Figure as the teaser and particles. They can appear either on the teaser or as a particle flying around. Also, the colorfulness is reduced by switching to the corporate design colors of gray-orange, which adds additional meaning and increases the informativeness of the colors. Additionally, the informativeness of colors is increased by coloring the buttons in the respective colors, e.g., the person button in light blue, the news button in green, and the organizational button in dark blue. Finally, the background of the particles in DetailView is colored in the respective content type color as a repetitive use of the colors to increase informativeness.

Group 1 – Version 2 The second UI version for group 1 almost remains with the same adaptations as described for version 1, but, in contrast to version 1, it solely increases the density to medium. Figure 7.7 displays an example of this UI, which enables a comparison of the density between all three UI versions: Baseline = low, version 1 = high, and version 2 = medium.



Figure 7.6.: Adapted UI for group 1 according to intercultural group profile calculated with average without misery strategy.



Figure 7.7.: Adapted UI for group 1 according to intercultural group profile calculated with fairness strategy.

Group 2 – Version 1 In the first adapted version of group 2 (Figure 7.8), the level of detail is reduced to low by removing the names of persons and organizational particles. Additionally, a button has been added to the DetailView to reduce information overload in this view. Moreover, the content selection strategy has been changed by adding more content-focused particles to the UI, which are, in this version, more green particles. Also, the informativeness of colors has been increased by coloring the buttons in the respective colors: green for news, light blue for person, and dark blue for organization. To further increase the informativeness, the background of particles has also been colored in the respective color of the content type.

Group 2 – Version 2 For the second UI version of group 2 (Figure 7.9), the functionalities were reduced by removing the teaser (microscope) and refresh button. Just as in version 1 of this group, the level of detail has been decreased as well in this version by removing the names and adding a button in DetailView. Concerning the colorfulness, the groups' preference was assumed to be low, but with a high informativeness of the colors used. To match these requirements, the color scheme was changed to the corporate colors for additional meaning, and the informativeness of colors is increased by coloring the remaining buttons and the DetailView in the respective color of the content types: persons are orange, organizations light gray, and news dark gray.

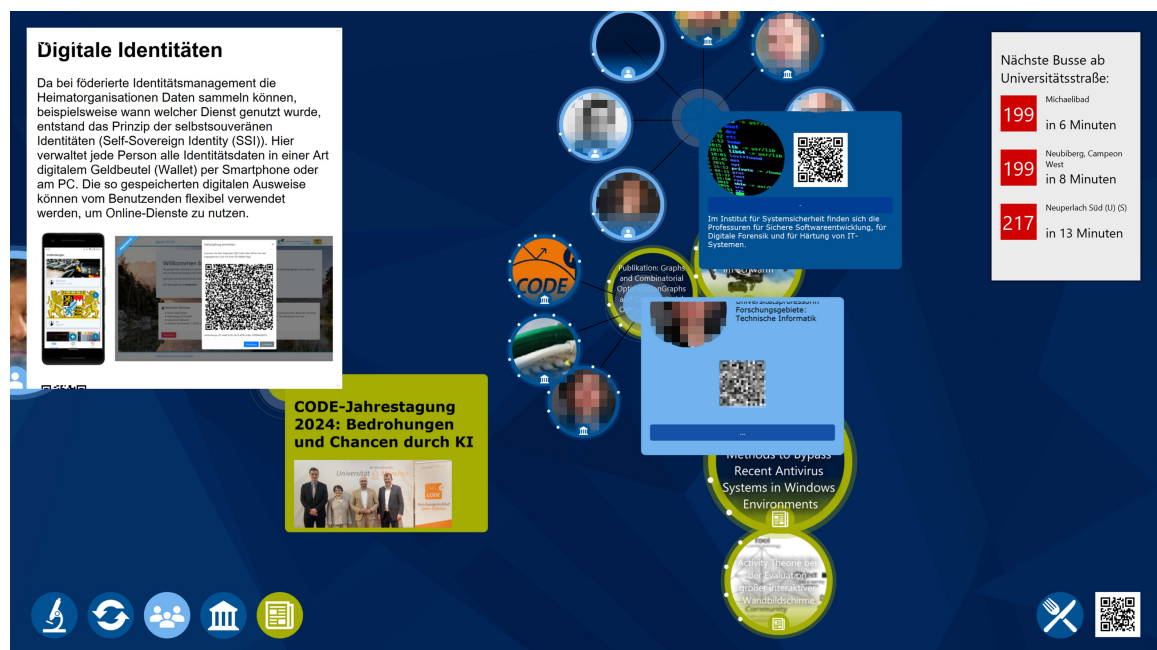


Figure 7.8.: Adapted UI for group 2 according to intercultural group profile calculated with average without misery strategy.

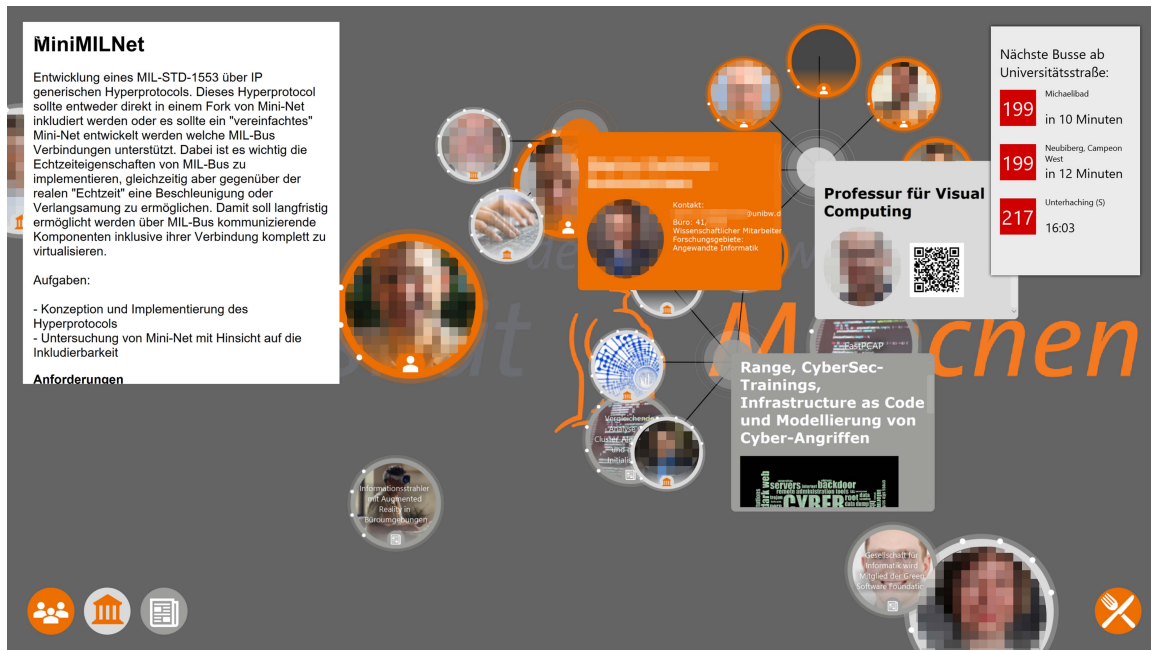


Figure 7.9.: Adapted UI for group 2 according to intercultural group profile calculated with fairness strategy.

Group 3 – Version 1 The first version for group 3 (Figure 7.10) adapted the density to medium and the content type to more formal, selecting more formal content visible as more green particles in FlowView. Moreover, the informativeness of colors increased to medium by coloring the buttons in the respective colors: green for content, dark blue for organization, and light blue for persons.

Group 3 – Version 2 The second adapted version for group 3 (Figure 7.11) reduced functionalities by removing the teaser (microscope) and refresh button, decreased the level of detail by removing the names of persons and organizational particles, adding a button in DetailView, and increasing density to medium, similar to version 1 of group 3. Finally, the colors' low colorfulness and high informativeness of colors are implemented by a corporate design color scheme and by coloring the buttons and DetailView in the respective colors of the content types: orange for persons, light gray for organizations, and dark gray for content.

7. Application-Specific Implementation



Figure 7.10.: Adapted UI for group 3 according to intercultural group profile calculated with average without misery strategy.



Figure 7.11.: Adapted UI for group 3 according to intercultural group profile calculated with fairness strategy.

Group 4 – Version 1 The adapted version 1 for group 4 (Figure 7.12) applied a low level of detail by removing the names of persons and organizational particles and adding a button in DetailView to reduce information overload. Additionally, the content displayed was more focused on formal content, which was implemented by increasing the number of content particles, the green ones. Finally, the informativeness of colors is changed to high by coloring the buttons and DetailView in the respective colors of the content types: green for news, light blue for persons, and dark blue for organization.

Group 4 – Version 2 In version 2 of group 4 (Figure 7.13), functionalities increase to high with new panels that appear when clicking on the organization or content buttons. The level of detail is reduced by removing the names from persons and organizational particles and implementing a button in DetailView. Moreover, the density is increased, and the colorfulness is reduced to low, implemented as a corporate design color scheme with only two colors: Gray and orange. This aligns with the preference for high color informativeness by providing additional meaning to the colors. Finally, the higher informativeness of colors is depicted by the colored buttons and DetailView in the respective content type colors: orange for persons, light gray for organizations, and dark gray for content.



Figure 7.12.: Adapted UI for group 4 according to intercultural group profile calculated with average without misery strategy.



Figure 7.13.: Adapted UI for group 4 according to intercultural group profile calculated with fairness strategy.

7.7. Verification & Evaluation

The final step is the verification and evaluation of the overall personalization approach. Therefore, as described in the evaluation concept (Chapter 6), a mixed method evaluation was conducted to verify the proposed approach and investigate improvements. The data collected during the on-site evaluation included a quantitative investigation of the UX with the UEQ-S for each group and all UI versions and a qualitative evaluation with transcripts of the think-aloud sessions and semi-structured interviews. While this section will only summarize the collected data, the next chapter will interpret it in detail concerning the overall personalization approach.

The entire dataset gathered for the UEQ-S for each version is consolidated in Appendix C. All transcripts from the think-aloud sessions and semi-structured interviews are available as open data [223]. The result of the UEQ-S scales for each group and all UI versions is presented in Table 7.13. Additionally, further tables provide an overview of the participants' actual preferences based on the semi-structured interviews and think-aloud sessions:

- Group 1 – actual preferences: Table 7.14
- Group 2 – actual preferences: Table 7.15
- Group 3 – actual preferences: Table 7.16
- Group 4 – actual preferences: Table 7.17

Table 7.13.: Result of the UEQ-S scales for all groups and all UI versions.

Group	Short UEQ Scales	Baseline	Version 1	Version 2
1	Pragmatic quality	0.917	0.625	1.458
	Hedonic quality	1.500	1.167	1.208
	Overall	1.208	0.896	1.333
	Diff to baseline	-	-0.312	+0.125
2	Pragmatic quality	0.167	0.667	0.917
	Hedonic quality	1.167	1.083	1.083
	Overall	0.667	0.875	1.000
	Diff to baseline	-	+0.208	+0.333
3	Pragmatic quality	1.417	0.875	1.667
	Hedonic quality	1.333	0.958	1.000
	Overall	1.375	0.917	1.333
	Diff to baseline	-	-0.458	-0.042
4	Pragmatic quality	-0.667	0.458	0.667
	Hedonic quality	-0.042	0.208	0.667
	Overall	-0.354	0.333	0.667
	Diff to baseline	-	+0.687	+1.021

Table 7.14.: Actual design preferences and rating of UI versions for group 1. Abbreviations: B = Baseline, V1 = Version 1, V2 = Version 2, x = not applicable.

ID	Rating			UI Aspects Actual Preference					
	1st	2nd	3rd	Function- nalities	Level of Detail	Density	Content Type	Colorful- ness	Informa- tiveness
158	V2	V1	B	x	x	V2	V1/2	B	V1/2
159	V2	B	V1	x	x	V2	V1/2	V1/2	B
171	V2	B	V1	x	x	B	V1/2	V1/2	V1/2
173	B	V2	V1	x	x	B/V2	V1/2	B	V1/2
177	B	V2	V1	x	x	B/V2	V1/2	B	V1/2
181	V2	B	V1	x	x	V2	V1/2	B	V1/2

Table 7.15.: Actual design preferences and rating of UI versions for group 2. Abbreviations: B = Baseline, V1 = Version 1, V2 = Version 2.

ID	Rating			UI Aspects Actual Preference					
	1st	2nd	3rd	Function- nalities	Level of Detail	Density	Content Type	Colorful- ness	Informa- tiveness
183	V1	V2	B	V2	V1/2	B/V1/2	V1	B/V1	V1
188	V1	V2	B	V2	V1/2	V1/2	V1	B/V1	V2
190	V2	V1	B	V2	V1/2	V1/2	V1	V2	V2
211	V1	V2	B	B/V1	V1/2	B/V1/2	V1	V2	V1
217	V2	B	V1	V2	B/V1/2	B/1/2	B/2	V2	V2
218	V2	V1	B	B/V1	V1/2	V2	V2	V2	V2

Table 7.16.: Actual design preferences and rating of UI versions for group 3. Abbreviations: B = Baseline, V1 = Version 1, V2 = Version 2.

ID	Rating			UI Aspects Actual Preference					
	1st	2nd	3rd	Function- nalities	Level of Detail	Density	Content Type	Colorful- ness	Informa- tiveness
219	V2	B	V1	V2	V2	B	V1	V2	V2
232	V2	V1	B	V2	B/V1	B	B/V2	V2	V2
235	V2	V1	B	V2		V2	V1	V2	V2
244	V2	V1	B	V2	B/V1	V1/2	V1	V2	V2
248	V2	B	V1	B/V1	B/V1/2	B	V1	V2	V2
250	V1	B	V2	V2	B/V1/2	V1/2	V1	B/V1	V1/2

Table 7.17.: Actual design preferences and rating of UI versions for group 4. Abbreviations: B = Baseline, V1 = Version 1, V2 = Version 2.

ID	Rating			UI Aspects Actual Preference					
	1st	2nd	3rd	Function- nalities	Level of Detail	Density	Content Type	Colorful- ness	Informa- tiveness
207	V2	V1	B	V2	B/V1/2	B/V1	B/V1	B/V1	V1
254	V1	V2	B	V2	B	B/V1		B/V1	V1/2
268	V2	V1	B	V2	B/V1/2	V2	V1	V2	V2
288	V1	V2	B	V2	V1/2	B/V1	V1	B/V1	V1/2
299	V2	V1	B	V2	B/V1/2	V1	B/V2	V2	V1/2
298	V2	B	V1	V2	V1/2			V2	V1/2

8. Results

This chapter discusses in detail the gathered data from the verification and evaluation step for the personalization approach to validate the proposed approach, identify improvements, and derive answers to open questions. Additionally, it will reveal whether the personalization approach is a suitable solution and derive answers to the overarching research questions. The first part provides an overview of the analysis of the collected data, explains the coding analysis, and presents the coding results to enhance the interpretation of the participants' ratings and design preferences. Building upon this analysis, the results of the group modeling strategies and the personalization approach are presented, along with their impact on UX.

8.1. Analysis Overview & Coding Analysis

First, the results for each group are analyzed and discussed to determine whether there is a clear preference for a UI version within the group. In case there is no clear preference throughout the participants' ratings, the reasons for this will be further investigated, such as which factors influence the ratings and preferences, why the group modeling approach led to the respective UI adaptations, and the successes and failures of the aggregation methods. Next, the interview transcripts are used to analyze each UI aspect to identify key insights regarding its impact on UX, likes and dislikes, relations between UI aspects, etc.

Finally, the key findings are summarized across groups based on the previous analysis steps. Therefore, the main insights regarding the group modeling methods are gathered to identify the most suitable aggregation method for cultural values. Finally, the positive or negative influence of the UI adaptations is summarized to show how this personalization approach impacts the UX.

Coding Analysis A coding analysis [2, p.141-143] has been conducted for the semi-structured interviews to identify the most critical aspects relevant to evaluating the adaptations. The think-aloud sessions were not the focus of this analysis as many aspects mentioned during the interactions themselves were irrelevant to the UI aspects of the study, and the interviews summarized the relevant aspects in more detail. However, the think-aloud sessions were used to clarify and identify preferences in case of unclear statements during the interview sessions.

Following reported suggestions on building reliability within the qualitative research [152], the following steps were taken to increase the quality of the coding analysis: Two researchers conducted the coding analysis, while in the beginning, two interviews were open-coded simultaneously. This result has been compared to identify a code system that covers all relevant aspects. Afterward, both persons coded all 24 interviews, and open questions or uncertainties

about understanding some statements were discussed. The result of the open coding analysis led to 117 open codes used. Based on these open codes, both persons conducted axial and selective coding. The final results of both were compared to identify differences and improve them. The open codes were grouped into related categories within the axial coding process. The previous 117 open codes were assigned to 41 axial codes. These axial codes have been further evaluated to determine patterns and overarching categories leading to ten selective codes. These ten selective codes summarize insights concerning the six UI aspects essential for the objectives of this study. Additionally, the comparison of UI versions and adaptations and how to handle different preferences were the main outcomes of this analysis. Furthermore, a small part also contained information about the general evaluation procedure and feedback about the display that is irrelevant to this study and could be ignored for further interpretation.

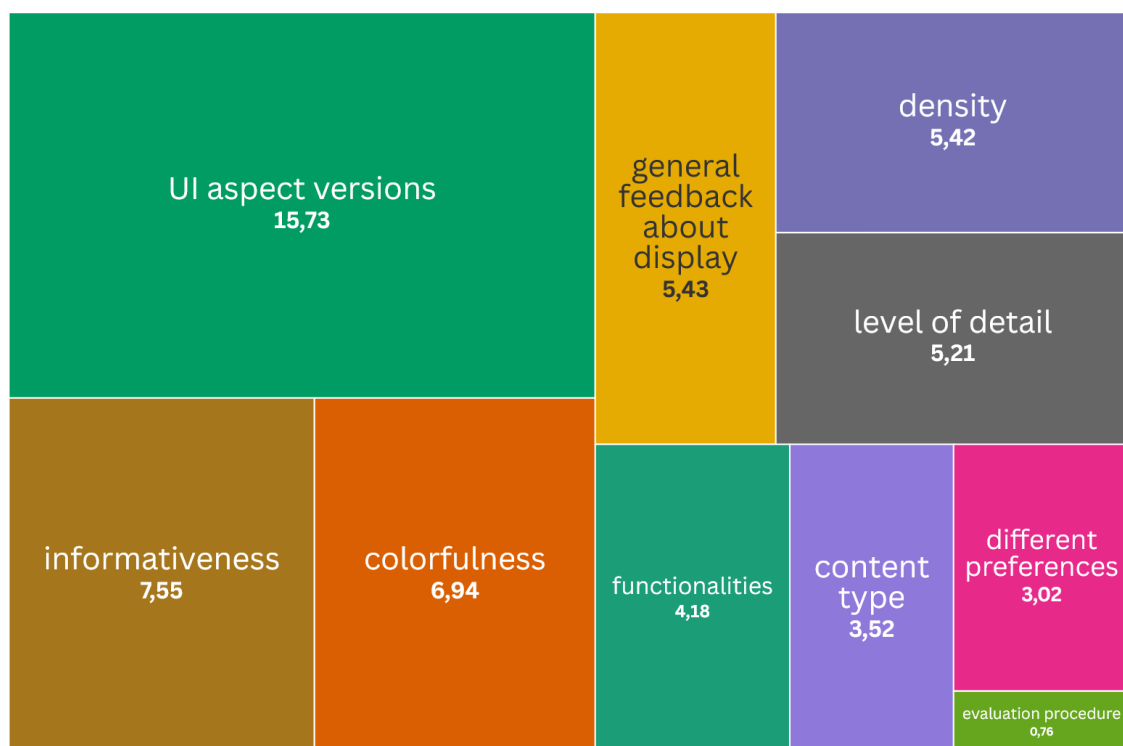


Figure 8.1.: Overview of the coding analysis result and the final selective codes and their share.

As an overview, Figure 8.1 shows the selective codes and the total frequency of the underlying axial and open codes. For more details, Figure 8.2 provides even more insights by displaying the corresponding axial codes and their share. These graphics give an impression of what was highly discussed in the interviews and which aspects are most controversial concerning how they match the user's preferences and impact the UX. The most discussed aspects in the interviews were differences between the UI versions and which adaptations were most liked or disliked (15.73). This shows that it matches the study objectives to identify whether and how the adaptations matched the user's preferences and impacted their UX. Among the most

controversial UI aspects, the informativeness of colors (7.55) and colorfulness (6.94) have been intensely discussed in most interviews. This shows the importance of these UI aspects for the intercultural adaptation approach. While the UI aspects density (5.42), level of detail (5.21), and functionalities (4.18) are of medium interest or tend to provoke discussion, the UI aspect content type (3.52) is the least controversial UI adaptation in this scenario.

This coding result is further used in the next sections to underpin and derive findings regarding the group modeling methods' success and failure, and to discuss the impact of the intercultural adaptations on the UX.

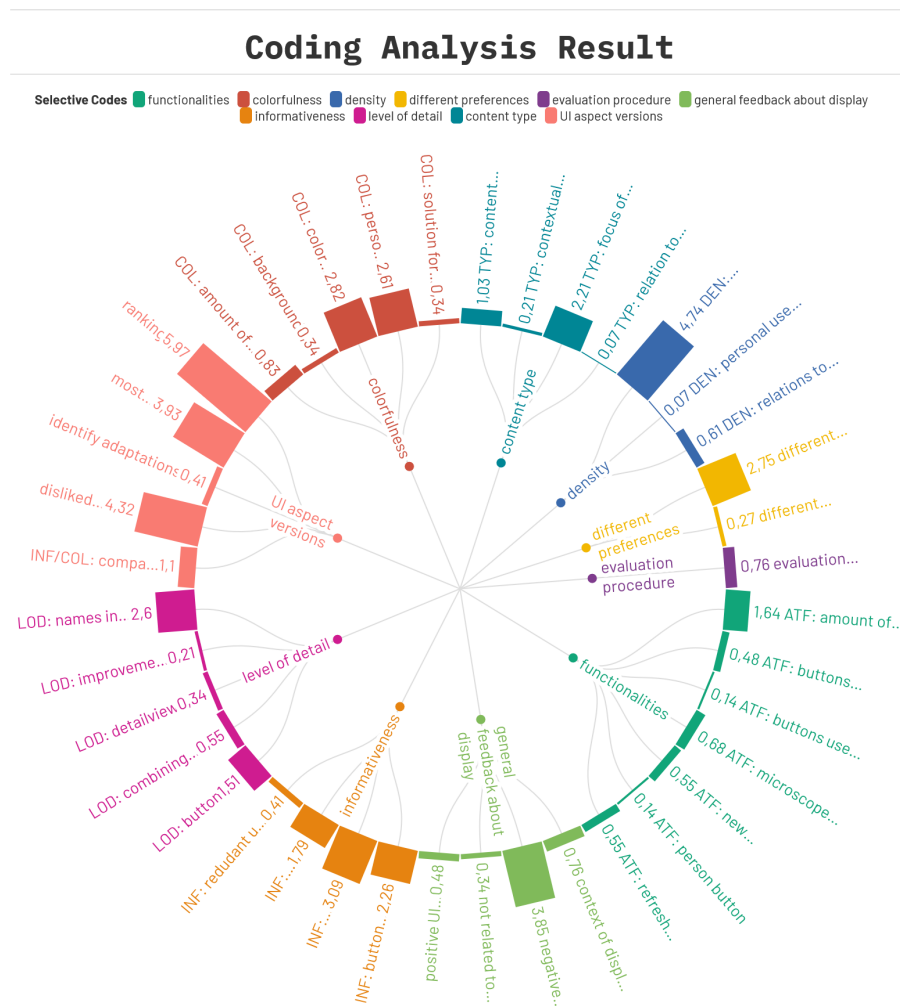


Figure 8.2.: Detailed result of the coding analysis with an overview of selective codes, respective axial codes, and their share.

8.2. Group Modeling Results

This section analyzes the successes and failures of the calculated intercultural group profiles. Therefore, the ranking of the participants, which UI version they would prefer the most and least, is evaluated by numbers and the qualitative data explaining why some participants liked one version more than another. This step identifies the most suitable UI version for each group. Moreover, the actual preferences according to the evaluation are compared with the assumed ones for the user modeling process. This reveals whether other preferences, personal ones, are more substantial than the culturally assumed ones. Finally, the group modeling approaches are analyzed by answering why specific UI adaptations were selected, especially if the participants did not like them.

8.2.1. Most Preferred User Interface Version

This part identifies the most successful UI version based on ratings and qualitative interview feedback. It will determine the most successful group modeling strategy for cultural dimension values. Therefore, the ratings and actually preferred vs. assumed UI adaptations are discussed.

Ranking

Participants were asked to rank the three UI versions they interacted with during the interview. Table 8.1 summarizes the votes for each version's first, second, and third place rankings across all groups. Version 2 performed best, ranked first 16 out of 24 times, and received 23 positive votes when combining first and second places, proving that it matched the participants' preferences. Most participants perceived this UI version as an improvement and preferred it over the baseline UI. The baseline UI was generally perceived as the least favorable, receiving 14 votes for third place. Even version 1 outperformed the baseline UI version, receiving 15 positive votes, accumulating first and second place, five more than the baseline version. Overall, both adapted UI versions were rated higher than the baseline version, indicating that intercultural adaptation of the UI led to a clear improvement, regardless of the group modeling strategy. However, when comparing the strategies applied, version 2 (fairness strategy) emerged as the clear winner, receiving ten more first-place votes than version 1 (average without misery strategy). The following section analyzes the ranking result per group in detail to substantiate this result further. The actual design preferences and rankings are displayed in tables within Section 7.7.

Table 8.1.: Summary of the number of placements on rankings for each UI version.

Ranking	Baseline	Version 1 (Avg Without Misery)	Version 2 (Fairness)
1st Place	2	6	16
2nd Place	8	9	7
3rd Place	14	9	1

Group 1 For the first group, the rating shows four participants nominated version 2 in first place and two in second. Consequently, version 2 is the group's overall preferred UI. Version 1 was voted the worst UI, with five nominations in third place and one in second. Aspects mentioned by participants that they did not like about version 2 were not as severe as they would not accept this UI version, which further underpins the success of version 2.

Group 2 Reviewing the ratings of the second group, versions 1 and 2 share equal nominations for the first place (each 3). However, version 2 also received three nominations for second place, but version 1 only had two. This indicates that overall, considering the first and second place, version 2 received more positive feedback. Consequently, it is the best UI version for group 2, followed by version 1.

Group 3 The third group voted for version 2 in first place with five nominations and one in third place. However, considering the participant's negative feedback about version 2, the personal aversion against the color scheme, and the drastic adjustment of the level of detail by removing the names were the reasons for this negative vote. However, the participant reported that even version 2 would be acceptable, as these negative aspects are not essential. Version 1 received by group 3 one nomination for the first place, three for the second, and two for the third. In comparison, the baseline UI received three nominations for second place and three for third place. This shows that version 1 is still rated higher than the baseline UI. In sum, version 2 is the best UI for this group, following version 1.

Group 4 The fourth group nominated version 2 four times in the first and twice in the second place, which is the overall preferred UI for this group. Following this result, version 1 was rated two times in the first, three times in the second, and once in the third place. Consequently, it has a higher ranking than the baseline UI, which received five nominations in third place and only one in second place.

This analysis shows that UI version 2, based on the fairness strategy, received the most positive votes and was preferred by most participants. While group 1 favored the baseline version over version 1, all other groups ranked version 1 higher. Subsequently, the adapted UI versions outperformed the baseline UI version in most cases. The following section provides a detailed analysis of liked and disliked adaptations, exploring why they were selected and offering insights into why version 2 (fairness) performed better than version 1 (average without misery).

Preferred UI Adaptations

In this part, the different UI adaptations and whether they were liked or disliked overall by the groups are summarized. Therefore, the adaptations received a "liked" if most of the group's users preferred the UI aspect in that specific adaptation degree. If there are mixed reviews within the group, the UI adaptation degree receives a "partially liked." With only one positive rating and five negative votes, the UI adaptation is perceived as "disliked." An overview of the adaptation's ratings is provided in Table 8.2.

Table 8.2.: Overview of liked, partially liked, and disliked UI adaptations summarized for each group. Abbreviations: * marks degrees of the baseline version, - marks degrees not evaluated by the group.

UI Aspect	Adaptation Degree	Ratings of UI Adaptations			
		Group 1	Group 2	Group 3	Group 4
Functionalities	low	-	liked	liked	-
	medium*	-	partially liked	disliked	disliked
	high	-	-	-	liked
Level of detail	low	-	liked	partially liked	partially liked
	medium*	-	partially liked	liked	liked
	high	-	-	-	-
Density	low*	liked	partially liked	partially liked	liked
	medium	liked	-	partially liked	disliked
	high	disliked	-	-	-
Content type	formal*	disliked	partially liked	disliked	partially liked
	formal only	-	liked	liked	partially liked
	formal + informal	liked	-	-	-
Colorfulness	low	partially liked	liked	liked	partially liked
	medium*	liked	partially liked	disliked	partially liked
	high	-	-	-	-
Informativeness	low*	disliked	disliked	disliked	disliked
	medium	-	-	partially liked	-
	high	liked	liked	liked	liked

According to Table 8.2, adaptations for lower or higher functionalities were consistently liked. Changes to the level of detail were only partially successful across groups. Concerning density, the participants disliked higher density (medium or high) throughout, while content type adaptations (including social activities and focusing more on formal content) were favored. Also, most groups preferred adapting to lower colorfulness, and higher informativeness of colors was always perceived as better than lower informativeness, making it a successful adaptation.

This evaluation revealed that the fairness-based group modeling approach performed best and can be recommended for aggregating cultural values. The following section analyzes factors for success and failure to investigate why the fairness strategy achieved a better result than the average without misery strategy in deriving an intercultural group profile. Specifically, it explores why certain disliked adaptations were selected, such as high density in group 1 and medium density in group 4. Additionally, the level of detail is revisited due to mixed feedback from groups 3 and 4, which only partially favored this adaptation, particularly the button in DetailView.

8.2.2. Factors Impacting Group Modeling Success

This section discusses the disliked and partially disliked UI adaptations for each group. Therefore, the reasons for selecting these adaptations and the factors impacting the group modeling success and failure will be analyzed. Finally, the group modeling approaches are compared, and the findings are summarized. As derived in the previous section, the following adaptations were not liked and will be analyzed in more detail:

Group 1 – High density in version 1 This adaptation was selected as the value for the cultural dimension LTO was high. This result of a high LTO value appeared as only one participant's value was considered for calculating the average. The threshold of ± 10 resulted in removing or ignoring all other participants' values (see Table 7.7 for more details). Even though some other groups also only considered one value in this dimension, it was in their favor that it was a low value and matched the preference for low density in the overall group (besides group 3). Overall, it must be said that it seems that the threshold of 10 is too strong, and it is essential to include as many values as possible to consider everyone's preferences.

Group 3 – Low level of detail in version 2 The low level of detail has been selected due to a high PD value for the group, which was higher ranked than the UA value. The high PD value was chosen in the penultimate round of the fairness strategy and considered essential for participant P248. Looking at the participant's ratings, the adaptation was only partially preferred as it was a drastic change by removing the names. Only one other participant (P235) had a high PD value and had no preference for this specific UI aspect adaptation. Looking at the other participants' values (Table 7.3), they would have been in the medium range and, thus, select the medium adaptation degree that would match most of their preferences. Switching the sequence of the last two participants would have led to a medium level of detail. This emphasizes the impact of participant order on the success and failure of the fairness strategy.

Group 4 – Medium density in version 2 The fairness strategy led to a medium density due to a medium value in the LTO cultural dimension based on the choice of P298. Most other participants also had medium LTO values, except participant P254 (value: 29). However, since this participant was second to choose, a different value for UA was selected, as it was more pronounced. While medium density likely aligned with most participants' preferences, other factors may have affected the success of this UI aspect. Comparing the group modeling result of fairness with the average without misery, it was advantageous for the group that all medium values were not considered due to the threshold of ± 10 , which led to a more preferred density adaptation. If another group member had a similar cultural background and thus similar values, that person could have selected this important value after P254, thereby contributing positively to the overall group's satisfaction.

Group 4 – Low level of detail in versions 1 and 2 In selecting the adaptation for the level of detail, group 4's ranking highlighted the relevance of the cultural dimension UA. Both group modeling strategies produced a high UA value. However, only two participants had high UA values, while four had a medium value. Within the average without misery strategy, the threshold of ± 10 led to ignoring two values that would have been decisive for receiving a medium value. In this case, the threshold hampered the success of this group modeling approach. For the fairness strategy, participant P254 selected this value for UA, which led to this adaptation that was only partially liked. Only drastically changing the order, e.g., switching position with P298, would have impacted this outcome and led to a medium level of detail.

Summarizing the analysis of why some adaptations were selected based on the group modeling result, we can draw the following conclusions regarding the group modeling strategies "average without misery" and "fairness":

Average without misery (version 1) The threshold of ± 10 in this group modeling strategy limited its effectiveness. Including all values would likely have resulted in a more favorable UI version. However, due to the threshold, some adaptations were selected that, in some cases, led to strong dissatisfaction with the complete UI version among the participants, emphasizing the threshold's negative impact.

Fairness (version 2) This group modeling approach led overall to high acceptance and good ratings. However, looking into the likes and dislikes of UI adaptations, the order negatively influenced the group modeling result, which aligns with already reported factors in literature [143]. Despite this finding, the dislike of one adaptation did not lead to overall aversion, as the other positive adaptations outweighed the negative ones. Consequently, looking at the total number of adaptations liked does not necessarily lead to the overall best UI version for the participant or group. Instead, it was the case that a certain adaptation, which was absolutely not or very poorly received, affected the overall success of the UI version. Considering this, the ranking and liked or disliked adaptations analysis shows that the fairness approach derived more adaptations that were liked or were strongly perceived as positive by the participants, outweighing negative ones and leading to overall satisfaction with this UI version.

8.2.3. Summary and Discussion

Summarizing the previous discussions and analysis of the group modeling strategy “average without misery,” it can be identified that the threshold of ± 10 negatively impacted its success. In the context of cultural dimension values, it seems essential to consider all values when aggregating and deriving the extent of the cultural dimensions. The disliked UI adaptations would have benefited from considering the other participants’ values, leading to a better overall result.

Reflecting on the group modeling strategy “fairness,” the order strongly impacted the success and failure of UI adaptations. Additionally, the number of participants with similar cultural values also impacts this strategy’s success: If more people in my group have similar values, more values will be selected that correspond to my own and, thus, to my preferences. However, overall, the influence of order has not led to extreme dissatisfaction with the UI version among the participants, as other UI adaptations were perceived as strongly positive, outweighing disliked or partially disliked ones. Subsequently, this strategy derived an intercultural group profile, leading to an overall positively rated UI.

Comparing the overall likes and dislikes of adaptations, version 1 (average without misery) did not contain many more disliked adaptations than version 2 (fairness). However, it was more negatively rated in the overall ranking. This means that most participants perceived the overall adaptations of version 2 better than those in version 1. Considering the overall success in the UI versions’ ranking and the strong positive feedback for version 2, the fairness group modeling strategy used seems to be the most promising. Every participant was allowed to select one cultural value that was most pronounced for them, which led to overall success for the group. However, the impact of order and similar participants needs to be considered.

8.3. User Experience Results

This section presents and discusses the users’ perceptions concerning the three UI versions: baseline, version 1 (average without misery) (V1), and version 2 (fairness) (V2). Therefore, the qualitative interview results for each group are investigated to identify what impacted the UX by analyzing each UI aspect tested in the adapted versions. Statements from the interview transcripts underpin the main insights; the original phrase is referenced if the interview language differs from English.

8.3.1. Group-Based User Experience Analysis

First, the different findings for each group are analyzed regarding whether or how the UI adaptations have impacted their UX with the CommunityMirror. As a basis, the interviews and discussions about which adaptations they liked or disliked will be used to analyze this impact. The qualitative feedback will support the understanding and enable drawing attention to impact factors for a successful intercultural personalization of large interactive displays in semi-public areas.

Group 1

The adaptations for all groups are summarized in Table 7.12. Since the UI aspects functionality and level of detail (both medium) were not adapted for this group, they were not discussed in detail with the participants. However, some participants (P171) mentioned that the functionality of the organizational and news buttons could be improved by highlighting the particles for a few seconds after clicking on one button to enable the user to connect the button symbol and the different content types. It appears that it irritates the users if nothing happens after they try to click the buttons with reduced functionality. The other UI aspects are analyzed in detail for this group in the following paragraphs.

Density The density for this group was evaluated in three different degrees: Low, medium, and high. The participants tested the degrees of density in the think-aloud sessions in the following order: low, high, and medium. Comparing the different densities in the interview showed that the participants were unanimous: the high density of version 1 was negatively impacting their UX. They stated it was overwhelming and confusing due to the number of particles displayed: “You can also see here with version 1 that it’s just too much. [...] It looks like a mess, it’s just too much.” (P159, 1), “So that was just too much.” (P173, 2), “Yes, two was too much for me right away.” (P177, 3). Also, disliking high density and, consequently, losing focus was related to the amount of text that was displayed in the particles: “If there is too much content, then too much text, and then, if there are also too many elements, it is difficult to concentrate.” (P181, 4)

Version 2 for this group with the medium density received the most positive or neutral feedback: “[...] for me this version was clearer.” (P181, 5), “But now, when you look at it like that, it can almost be a bit more (than baseline)” (P159, 6), “I think it’s probably, uh, better in terms of the information flow that more of these bubbles fly (around).” (P158, 7)

However, some also especially enjoyed the baseline version with low density “because you simply had the time to choose something. [...] If you then say, okay, I’m not interested in anything, you can always press the refresh button.” (P173, 8), or it was just a feeling: “From a gut feeling, I think the blue one is actually the best.” (P171, 9)

Interestingly, the density was also related to the display’s usage context: If people have a lot of time standing in front of the display and are willing to wait until something interesting appears, low density might be good: “If you like a lot (content) and you might be standing in front of the thing for half an hour, you’ll probably need this version” (P159, 10). However, if time is more restricted, medium density would be preferred: “[...] then I have the feeling [...] that (when) I’m standing in front of the screen as a user, uh, the information should show through the bubbles as quickly as possible. And I can quickly click for the information I’m looking for.” (P158, 11).

Another intriguing finding is that the density was observed to influence the speed perception of the particle’s FlowView strongly: The more particles, the faster they move, and the fewer particles, the slower they move: “Well, here it appeared slower. Here, there was just so much dynamic that it just seemed faster. If you compare the two.” (P159, 12), “Although, perhaps there were fewer elements [...] but the movement was different, the speed.” (P181, 13)

Choosing the appropriate density appears particularly challenging as there appears to be a narrow degree between absolute aversion and acceptance. The dependence on other UI aspects further underpins its complexity. However, especially the UI version with high density strongly negatively impacted the UX and was the most frequently mentioned aspect when asked for the most disliked adaptation as it made them feel overwhelmed, which is shown by this key statement of a participant: “But you shouldn’t feel overwhelmed by the screen, right?” (P158, 41) One solution to match this aspect better with the current user’s preferences could be to invite them to customize the density as mentioned by a participant: “Let me put it this way: it’s not something for which there is no technical solution, programmatically, with some kind of toggle or something, so that you can simply use sliders to set how much content you want, or how little content you want, or anything like that.” (P158, 42) Therefore, deciding on high density should be done carefully and re-evaluated to match the users’ preferences or more user involvement should be considered in this specific regard.

Content Type In addition to the baseline UI, which featured a balanced mixture of people and other professional content, both adapted versions contained more informal content, such as information about social activities (bike tours, company parties, conference visits, etc.). Throughout the group, the participants unanimously preferred the adapted versions, including social activities: “I liked the social event as information very much. I would go for the two versions.” (P158, 14), “So for me, because I’m not a subject matter expert, this version (1/2).” (P181, 15), “So of course from the group, so from the left side (versions 1 and 2).” (P171, 16) This was further substantiated as one of the most helpful adaptations within the interview as it was presumed as “[...] a bit younger, a bit more upbeat in terms of content.” (P158, 17) and they appreciated that “it’s not only work, but also something that affects the work around it. And then you also have that a bit in your mind, unlike only stiff.” (P177, 18)

This shows that including social activities can positively impact the interaction with such devices. Further, it can also support increasing awareness for the overall activities within the teams by sharing more informal content, which could further lead to making the other formal content more consumable as it was presumed to be content “that was a bit drier” (P159, 19).

Colorfulness and Informativeness of Colors As this UI aspect is closely related to the informativeness of colors, both factors are discussed here. Based on the group modeling, the preference for a less colorful UI was identified for both versions. However, the informativeness of the colors used should be high. To match this specific combination, the overall UI color theme changed to shades of gray and orange as they are less colorful than blue and light green and provide additional meaning as corporate colors. Additionally, the buttons and the background of the particle’s DetailView are changed to the respective colors of the specific content type to ensure high informativeness of the colors by repetitive usage.

The adapted versions’ color scheme was not clearly favored initially; only a few participants preferred that scheme over the baseline. However, the informativeness of colors within the adapted version was preferred over the baseline UI. The interview results are discussed in detail in the next part to understand this more ambivalent result better.

First, the baseline implementation will be discussed, including the likes and dislikes of the color scheme. Participants reported some feeling of familiarity regarding the blue-green color scheme and personal meanings behind the colors: “I liked the [baseline] version better because I felt it was more modern, futuristic and not so traditional.” (P181, 20), “But I’m just a bit calmer. So, just this blue and then [...] yellow-green. I just thought that they went very well together. [...] I don’t know why, but yes. Maybe you’re used to it. [...] It’s more soothing for my eyes, not like the orange, then accordingly.” (P177, 21) Besides these positive comments, some critics also appeared in conversation with others, e.g., “Everything, it is so blue and blue, relatively boring, looks like a Windows 8 background.” (P159, 22)

Second, the color scheme of the adapted versions is discussed. In contrast to the baseline version, the adapted UI received major personal aversions from the participants against the gray colors: “it’s not my color” (P173, 23), “Obviously, I just think gray is an absolutely awful color, but that’s just a personal [...] feeling.” (P177, 24) However, most participants, even those who preferred the baseline version in the end, also appreciated some aspects of the new color scheme as it looked more professional, like something new, improved user guidance, or made the interaction more fun: “In terms of design, there is a clear leap from the baseline to version 2. [...] There is a bit more love in this one. There is a bit of gray in the gray, so you could maybe work a bit on the nuances. [...] Yes, orange is just a bit more fun to look at than blue on blue.” (P159, 25), “Well, from a marketing point of view, I would of course say that the orange one is better because you just get stuck on the people.” (P171, 26), “It takes getting used to it because it’s just not... and with the gray, but still very nice. So I would like it too.” (P177, 27) As negative aspects, this less colorful UI version caused discussions about whether the gray symbolized a kind of “boredom” and the orange color appeared aggressive to some: “...a bit of boredom from the background now with the University of Bundeswehr and all that. It was a bit too traditional for me, too much of an institution, so to speak.” (P181, 28), “Yes, our orange kind of yells at you a bit.” (P173, 29)

These ambivalent discussions with many participants about whether or not they like the adapted color scheme show that the participants’ aversions to gray colors may also have hampered their ability to decide whether the interaction with a less colorful UI was better. As a result, it is even more important to look at the other color-related aspects, from the informativeness of colors, that further impact the UX (differentiation of content, meaning of colors), and consider that personal feelings towards some colors impact the UX.

When differentiating the content types from one another, the adapted version with the less colorful color scheme led to high acceptance among the majority of the group: “So in terms of meaning, it was simply easier to distinguish between the institute, people, and news here. Which was simply a bit clearer than the light blue and the dark blue, so to speak.” (P173, 30), “I think this one was more intuitive. Okay. It was easier for me to distinguish the content.” (P181, 31) However, less colorfulness results in less contrasting color scheme, which also causes issues such with identifying differences, e.g., of the background (“That is also the case, for example, with the university logo, which is barely visible because it is so gray and gray.” (P159, 32)).

The higher informativeness of colors by repetitive use, especially the buttons, was mentioned as one of the most helpful adaptations within the interviews. This further underpins the positive influence on the UX: “There you can see that you have different icons for different functions. It’s very clear and it’s also easier. And that’s what appealed to me the most, that change.” (P158, 33), “Well, if I had to say it spontaneously, yes, of course, the buttons down here.” (P171, 34)

Regarding the ability to differentiate the content, it was appreciated that in the baseline version, the person and organizational particles were similar in different blue shades as “[...] professorships were related to persons.” (P171, 35) However, in the baseline version, all buttons have the same colors, which was highly criticized as they were not prominent and clear to some: “But based on these keys, I have seen that is not clear at all. They have absolutely the same color but different functions.” (P158, 36)

The participants especially appreciated the matching color scheme of the adapted versions with the corporate colors as it gave them a sense of belonging: “On the other hand, as I said, I got this feeling of belonging and warmth a bit more, so to speak.” (P181, 38), “[...] the connection to the organization, definitely. Yes, I like that.” (P158, 39), “Then, of course, the orange, because it has that corporate identity, the colors.” (P171, 40)

Reflecting on these detailed discussions, we draw the following conclusions regarding how colorfulness and informativeness of colors impact the UX: Within this group, the adapted version for informativeness with colored buttons and the matching corporate design colors was the right choice. It enabled easier content differentiation, a more professional look and feel, and established a connection to the company that most users appreciated. Personal aversions to colors impacted whether participants disliked some UI versions, but that does not necessarily prove whether this results in a better or worse UX. Thus, additional aspects, such as the informativeness of colors, should be considered when deciding on a specific color scheme. To underpin this result, personal aversion to the gray-orange color scheme was further discussed in the interviews, and all participants reported that they would also be okay with the new color scheme as it also contains many advantages, especially regarding the informativeness of colors. However, it has to be considered that the lower colorfulness might lead to fewer contrasting colors, so choosing the few colors available should be done carefully.

Overall Impact on UX In conclusion, the adaptation based on the intercultural values of their group profiles, especially version 2, resulted in a more positive UX for this group. While the change of color scheme was not necessarily everyone’s preference due to personal aversion against gray, the other adaptations outweigh this aspect, especially the change of content type, including social activities, and the higher informativeness of colors. Comparing this result with the UEQ-S of the first group (Table 7.13), the overall quality for version 1 was rated lower than the baseline version. This result may occur as the adaptation in this version, the high density, strongly impacted the UX for all participants. Moreover, version 2 shows an increased overall quality with +0.125, especially within the pragmatic criteria. This result further underpins the qualitative evaluation, which revealed a higher UX while interacting with version 2, the adapted version using the fairness strategy for group modeling.

Group 2

The adaptations for all groups are summarized in Table 7.12. All UI aspects, besides density, have been adapted in at least one UI version for this group. The following paragraphs discuss each UI aspect, its differences, and the corresponding interview results describing their impact on UX.

Functionalities The fairness aggregation leads to lower access to functionalities in the second group. This has been implemented by removing some buttons (refresh and microscope), reducing the ability to manipulate the UI. The majority of the group preferred the version with fewer buttons as the purpose of the refresh and microscope buttons was not always clear: “So, the fewer buttons, the better.” (P183, 43), “But here is this microscope. What was it for then? [...] I liked the fewer buttons better. [...] That’s not something I can say is absolutely necessary.” (P188, 44), “I didn’t understand the (microscope) button. [...] So, the (refresh) button is useless to me.” (P217, 45), “The research one (microscope button), I’m not a fan of it myself. [...] If it’s not there, I will be ok.” (P218) However, a participant saw an advantage of the refresh button: “It can be overwhelming for people to have so many things on the screen, and they want to clear out the screen completely. They need to have this one.” (P218) Nevertheless, the refresh button’s purpose is to refresh the displayed content and, through this, explore other content, not necessarily clearing the display itself.

In total, reducing the number of buttons seems to be a good adaptation for this group as the purpose and functionality of the removed ones were not clear to most of the participants. However, this positive influence on the UX by simplifying the UI through button removal only relates to buttons that do not fulfill a purpose or add an advantage to the interaction.

Level of Detail The adapted UI versions for this group both applied a lower level of detail to the application, which led to removing names of persons and organizations and introducing a button in the DetailView of the particles to separate the basic content from additional information.

Most of the participants appreciated the removal of names for various reasons. One was that the reduced information load simplified the FlowView compared to the baseline version, which was perceived as overloaded (“No, this (B) was too much for me.” (P190, 46), “Well, I liked the (V1/2) better.” (P211, 47), “[...] what I liked the most was that the names on the icons (particles) were not there anymore. That helped a lot.” (P218) Another aspect mentioned positively concerning the missing names was that they were not interested in the persons at all, and removing the names made it easier for them to ignore such particles: “Well, apart from the fact that, as we said, I don’t like that with the people anyway, but, um, I thought the fewer, the better.” (P183, 48) Interestingly, some participants did not even notice that the names were removed: “Since I didn’t notice that, I would say that it doesn’t really matter whether there is a name on it or not. [...] Here, I forgot the name again. You see? Then you don’t need the name.” (P188, 49). However, one participant described that the names cover the important task of enabling recognizability: “[...] if you get to know the people now, so you’ve heard a name and then you have a face to go with it, I think that’s helpful.” (P217, 50)

The button in the DetailView of the particles enabled a separation of the content and reduced the information overload at first sight. It was overall positively rated (“Uh, yes, I definitely liked it.” (P217, 52)) as the baseline version contained too much text presented at first sight in the DetailView (“There (B) was maybe too much text. I mean, too much information.” (P190, 51)).

In sum, the button in DetailView to separate a lot of content at first sight positively impacted the UX. Furthermore, removing the names of some particles from FlowView, leading to a lower level of detail, was also rated as a helpful adaptation within the group as it simplified the UI and thus positively impacted UX. However, the purpose of the application is relevant when deciding to remove specific information from first sight, and in case recognizability is not necessarily the overall application’s target, it may be a suitable adaptation. Otherwise, it may be a too drastic change, and reducing other information needs to be evaluated.

Density For this group, a low density was applied to all evaluated versions. Interestingly, although all versions used the same density, some participants still perceived differences. This shows that other UI aspects influenced the perceived density. For example, particles are perceived to be larger in the adapted versions than before, related to a lower level of detail, as names of persons and organizational content have been removed: “I had the feeling that the circles were a bit larger in the second version (V1/2). [...] I liked that better than the small ones because with small ones you can’t read what’s written inside so well.” (P188, 53)

Another finding is that suitable perceived density depends on the amount of text displayed: The more text displayed in particles, the more overwhelming the number of particles felt for the participants as they needed to read more while observing the FlowView. This may be influenced by the level of detail chosen at first sight or the percentage share of the selected content type as in the case of more content particles (news, publications, etc.), more text is presented in the particles in FlowView. Participants reported that “Here (B) was more content and it took me longer to register the content. [...] Because I had less to do on the tiles here (V1/2), I would look at them immediately; there could be more.” (P217, 54)

Also, the color selection and whether it pinpoints specific parts of the displayed particles impacted the UX concerning density: “These two (B/V1) were very overwhelming for me. [...] The colors and background. [...] This one (V2) was less overwhelming for me. I don’t know if it was because of the colors or it looked more simple, the UI.” (P218)

Even though all versions had the same density, it was interesting to find out that the perceived density, whether users could spot all relevant information or felt comfortable with the number of particles displayed, differed depending on the level of detail shown at first glance, the content selection (percentage of specific content), and the colorfulness.

Content Type While the baseline and version 2 had a more balanced content selection between people, organization, and other content, version 1 had a higher percentage of content (news, publications, etc.) in the selection strategy, which put more focus on the formal topics the company is working on. The questions asked during the interaction phase and in the interview focused on whether the participants preferred to connect with other people through the content particles or scroll through the person and organizational particles. Most group members preferred version 1, which focused more on content particles. It was also one of the most mentioned UI aspects when asking for the most helpful adaptation. One reason mentioned was that they were not necessarily interested in the person particles as they did not know the persons displayed. Subsequently, there was no purpose in recognizing the person by name or picture. It felt weird to them to click on a person without intention: “So, I would say that the green one, the one with the information, is better if it is a bit more, because the people usually don’t bring that much.” (P188, 55), “So you know, I’m just absolutely not interested in people displayed there. [...] So, me personally now, right? Besides, I don’t know most of them anyway.” (P183, 56)

Focusing on more content than people and organizational particles was a good adaptation for this group. They preferred to read about the topics the employees were working on as they did not know the people displayed. However, this might change if the purpose of recognizability is targeted. For the UX, the more interesting particles were the content particles. Most participants did not see the purpose of selecting or browsing through person particles without intention. This shows that the purpose of including person particles must be transparent to the users, and the UI should enable related tasks to explore such content type, e.g., looking for a specific person to get information on how to contact them.

Colorfulness and Informativeness of Colors Version 2 used a less colorful UI, but as high informativeness was also required, the color scheme switched to corporate colors, which have been repetitively used in *DetailView*. The baseline and version 1 remained similar regarding the colorfulness (medium). However, in version 1, the high informativeness was implemented by repetitive color use in buttons and the *DetailView* of the particles. Most participants preferred version 2 concerning the colorfulness and informativeness of colors.

The gray-orange color scheme in version 2 was a clear favorite for most participants, especially because of the meaning of the colors as they belong to the university: “But I think the orange goes very well with the Bundeswehr.” (P188, 57), “This (V2) is great for me because those are the colors of the university. I would keep that.” (P190, 58), “So (regarding) color choice was that (V2) clearly my favorite.” (P211, 59), “gray-orange (V2) simply matches the Uni logo.” (P217, 60) Also, the reduced amount of colors was perceived as helpful in decreasing information overload and thus positively influencing the UX: “And then here (V2), the color scheme and the simplicity is the big bonus for me.” (P218), “That (B) has too many colors.” (P190, 61)

The gray-orange color scheme was mainly criticized due to personal aversion to the color gray, though it did not directly affect the UX: “Well, the gray thing, I thought it was all a bit... Well, I don’t find that beautiful, let’s put it that way.” (P183, 62)

Only a few preferred the blue-green color scheme versions as it was aesthetically more beautiful to them: “Regarding aesthetics... //S01: Did you think that (B/V1) was more beautiful?// Yes, exactly.” (P188, 63) A negative aspect mentioned regarding the blue-green color scheme was that it is nothing special and does not have any additional meaning: “This blue color scheme is just, it looks nice, and thing... but you see it 10,000 times.” (P217, 64)

Concerning the informativeness of colors, not only the corporate design and thus the additional meaning of colors was rated positively, but also the higher informativeness by coloring the buttons was perceived as extremely helpful for the interaction from most participants: “So here it is better because you can also distinguish the buttons that way.” (P188, 65), “Here you already have the thing when you use it, that the buttons should also have the colors of the tiles, so that they are easier to assign.” (P217, 66), “because the icons had, like better color scheme, I would say. Like, it was easier for me to notice this reference on the buttons.” (P218)

However, using the less colorful scheme puts the focus more on person particles with the orange color than on others, which may be difficult as other particles are not in focus during the interaction as mentioned by a participant (“Then I have the news that are added to interact with. But they are not necessarily in the foreground.” (P217, 67)).

For the colorfulness, the adaptation towards a less colorful version was a good solution for the group; however, considering that the informativeness of colors increased. Especially the meaning of colors by using a corporate design color scheme was one of the most mentioned positive adaptations as well as the repetitive use of colors within the buttons, which impacted UX positively. It must be considered that the few colors in a less colorful scheme must be chosen in alignment with the overall objective and put on the right parts users should focus more or less on (“And depending on whether the goal is to introduce people, this orange accent, which is an accent color, is also there for the people, so to speak.” (P217, 68)).

Overall Impact on UX Overall, the adaptations of either version 1 or 2 positively influenced the UX for the second group based on the reported aspects or versions they liked or disliked. The most outstanding adaptation was the stronger focus on formal content in version 1 and the higher informativeness in both adapted versions. Based on the participants’ ratings, while versions 1 and 2 shared equal mentions in the first place, version 2 had a slightly better position than version 1 when looking at the second place. Consequently, the adapted versions based on the intercultural group values can be seen as a successful personalization for improving the UI and its UX. The UEQ-S additionally confirms this result for this group (Table 7.13), which shows an increase in the overall quality for both adapted versions, +0.208 for version 1 and +0.333 for version 2, especially improving the pragmatic quality of the UX.

Group 3

The adaptations for all groups are summarized in Table 7.12. For group 3, all UI aspects have been personalized in either version 1 or 2 based on the intercultural group profiles. Their impact on the UX is analyzed based on the interviews and summarized in the following paragraphs.

Functionalities For the third group, the group modeling method of fairness led to lower access to functionalities. Consequently, some buttons were removed in version 2. Most participants preferred this version with reduced functionalities for simplicity and the unclear purpose of some buttons, which was also perceived as the most significant adaptation.

They preferred fewer buttons as it made the UI simpler, more intuitive, and cleaner: “[...] the (V2) is definitely more pleasant, much better. It’s much tidier and... [...] doesn’t confuse me.” (P219, 69), “[...] I just found that (buttons) was clearer and more straightforward in terms of the associations.” (P232, 70), “Since it’s intuitive.” (P235), “And here I see that in the last version (V2) there has been a further simplification, that some control elements that I personally do not consider important have simply been removed and do not distract me additionally.” (P244, 71)

The unclear purpose of the refresh and microscope button was one aspect of why users did not feel the need for these functionalities: “That updates the screen. You can leave that out anyway. It’s not necessary. [...] Exactly, this microscope was there so that you could click through to the content from the teaser. [...] Okay, okay, yes, that’s nonsense.” (P219, 72), “[...] the refresh button, that’s also not really necessary. [...] There are always new ones coming anyway.” (P232, 73), “As I don’t find a big use of the refresh buttons and the other button we have.” (P235) The sole participant who preferred versions with more buttons (P248) suggested separating the position of operational buttons, e.g., refresh, from other content-related ones.

For this group, the fewer buttons had an overall positive impact on the UX. Reducing functionalities reduces the complexity of the UI for the user, which positively influences the UX. In total, it should be noted that the purpose of buttons should be clear and advantageous for the user to fulfill specific or operational tasks. Otherwise, fewer functionalities seem more favorable for the UX as it is easier for users to comprehend what they can do with the UI and are not overwhelmed by too many buttons that they question. If operational buttons are required, they could be hidden in another menu, but should not appear at first sight.

Level of Detail Applying the fairness method for group 3 led to a lower level of detail in version 2. This means the names of persons and organizations have been removed, and the text in the DetailView of the particles has been separated by a button that expands the additional text in case more information is available for that particle. Within this group, only two people were fine with the overall reduced level of detail. Removing the names in FlowView from persons and organizational particles was one of the most controversial adaptations and was highly discussed.

On the positive side, some participants did not mind the removal of names (“But it’s not necessary. I mean, it’s not mandatory. If it’s something, like, good to have. But if it’s not there, it’s not a big problem for me.” (P235)) and even mention it as most helpful adaptation: “[...] leaving out the information in the individual bubbles was quite good. Indeed, yes. I hadn’t considered it that way, but when I saw it, I realized it was more pleasant for me.” (P219, 74) Others partially liked this adaptation as the person button resolved the issue of looking for a specific person but not knowing what they look like (“[...] as soon as I clicked on the people button, I had my directory of names, and it was sorted alphabetically. That’s what it does for me when I can then jump into the people from there, so to speak.” (P244, 75)).

On the negative side, participants noted that the missing names removed the purpose of displaying these particles on the FlowView at all, especially concerning the organizational particles: “Because the professorship might then also say something to me when I’m standing there, oh yes, I have to talk to the colleague from [...] Professorship for Usable Security and Privacy, would perhaps make me more likely to click on a professorship.” (P244, 76), “This takes the greatest benefit from the people [...]. With the people, you could still live with it. With the projects, with the institutes and professorships, it should actually be there. [...] with the institutes, you would otherwise have to know by heart which institute has which picture.” (P250, 77)

The button also received mixed feedback. Positively, it was noted that participants did not feel overwhelmed when scrolling through the DetailView: “I also prefer the dots [expand button in DetailView], when we click on a professorship or Professor and then you get their first information first. And then when you tap on it, it extends a bit.” (P248), “Ah, I really like the folding out. [...] And so you at least decide, okay, I want to read more about this now.” (P250, 78) Negatively, some participants did not see the advantage or purpose of the additional step required to receive all the information available: “[...] if you click on it, you want to find out more, which means that if it’s no longer there, it’s more of a bother, because then the information isn’t immediately available [...]” (P232, 79), “So here, this additional clicking downwards I would refrain from if I, so scrolling with my finger does it for me.” (P244, 80)

The adaptation of this UI aspect was highly discussed, and mixed feedback was received. Only a few positive aspects could be reported for a few participants, which made the interaction with the UI simpler. However, removing names for persons and organizations might have been too drastic. Consequently, the names of the organizational particles, such as the button in DetailView, would be advantageous for the group. The button in DetailView also received mixed feedback, but it was not necessarily that decisive as to whether it improved the UX. Thus, the positive feedback enhances this reduced level of detail. This case shows that the adaptation is highly complex. It led to various adaptations, making it challenging to identify whether it positively impacted the UX. For this group, the adaptation of the level of detail was too drastic.

Density The density for the adapted versions has been increased to medium for this group. This adaptation received mixed reviews. The higher density was especially perceived as positive in relation to another adaptation, the changed color scheme (“In version one, I find it overwhelming with a lot of bubbles, even though it’s the same. I found it too much, maybe because of the color background, eventually. In version two, it was easy, even though it’s many bubbles. I was able to follow. And it was not too much disturbing.” (P235)) or neutral to others (“I have no problem dealing with this version (V1), with this amount of information [...]” (P244, 81)). Some participants preferred lower density because it was more manageable for them: “[...] rather than too much information, too dense, too many overlaps, not a fan of it. [...] I don’t want to use that much of my brain power to go through things. I prefer low density basically for that reason. It’s very simple.” (P248), “But I would say, preferably a bit slower and more organized.” (P232, 82)

Density was again associated with speed, which was negatively and neutrally rated by the participants: “It shows up slowly and it’s sort of a more calming experience.” (P248), “But, as stated, I don’t find the speed disturbing or too fast either.” (P232, 83)

For this group, the increased density in the adapted versions was acceptable overall, especially in relation to the adapted color scheme of version 2. Additionally, the speed could be reduced to counteract the negative perception that a higher density increases the speed of the particles.

Content Type For this group, version 1 focused more on formal content by displaying proportionally more content particles than persons and organizations. The vast majority preferred this adaptation. On the positive side, participants reported that they liked to learn more about the research findings: “But it is definitely interesting for me to see any interesting information, news, publications, any dtec or annual events, what are the insights.” (P219, 84), “The version one was quite handy in terms of information.” (P235), “[...] and there were actually articles in it that appealed to me, whereas I have less to do with the people at this point.” (P244, 85), “[...] we want to know more about its work, its research. So I would say that would be what I want to see at a display in a university or department to see their work.” (P248) However, one participant mentions that the more balanced number of persons vs. content particles is advantageous as it is more diverse (“I think it’s better balanced, so people and content, simply because it’s more varied.” (P232, 86)). An important aspect mentioned was the contextual use of such a large interactive display that also impacts whether the focus should be more on the people or the topics (content) they work on: “[...] if the Mirror is now aimed at people who come from outside of here, some kind of, I don’t know, employees from other universities, there just has to be a mix behind it.” (P219, 87) Interestingly, some participants report that they are not necessarily interested in the persons displayed as they do not see a relation to them (“I have less to do with the people at this point.” (P244, 85), “I’m not really interested in the people.” (P248)).

This group benefited from the adaptation to a more content-focused UI. However, the contextual use of the display needs to be considered as well as whether users have a relationship with the persons displayed, for instance, working colleagues, or they are looking for a specific person.

Colorfulness and Informativeness of Colors The first adapted version of this group regarding colorfulness applied a medium amount of colors and, thus, the same color scheme as the baseline UI. However, the informativeness of colors was calculated as a medium for version 1, which resulted in colored buttons. The second adapted version applied low colorfulness and high informativeness of colors by adapting the color scheme to corporate design colors and repetitively using these colors in buttons and the DetailView of particles.

Most participants preferred version 2 concerning these UI aspects throughout the whole group. The reduced colorfulness was perceived as more consistent color use, organized, eye-catching, and “(i)t’s minimal.” (P235): “[...] it is simply more appealing and clearer [...] appeals to me the most (V2). I also find it more eye-catching.” (P232, 88) The color scheme was often mentioned as one of the most helpful adaptations.

Regarding the informativeness of colors, the color scheme of version 2 was rated positively due to the matching colors with the university: “[...] also somehow represents the colors of the university, which is quite good.” (P219, 89), “If I was a company or a university, though, I would personally of course prefer it if my corporate color palette were somehow represented in there, and that might turn out more or less luckily.” (P244, 90)

Concerning the differentiation of content, version 2 was also perceived as an improvement towards this criterion as it was easier to focus on specific content: “For example, I was able to better classify that orange next to Professor [ANONYM] refers to persons and that gray and white contains information. [...] I then perceived that more quickly.” (P219, 91), “Whereby here (V2) one must of course say [...] it has a certain focus, but if you say that there was the same amount of information in both (V1/2), my brain here (V2) found it easier to filter out.” (P244, 92), “Whereas when I’m searching for text, I ignore the person and filter it more. [...] Definitely the (V2). It was just much easier to break down and assign.” (P232, 93)

However, some participants reported difficulties differentiating the content as the low colorfulness resulted in various shades of gray that negatively impacted this aspect: “[...] in version two, the contrast from content to background was too low.” (P235), “[...] the only thing I found was the gray circles for both the content as well as Professorship, although it’s dark and light.” (P248)

Regarding the repetitive use of colors, the colored buttons were noted as strongly helpful in identifying associations and differentiating the content, also when asking for the most helpful adaptation: “[...] but here (V1/2) you can see the clear connection.” (P244, 94), “[...] how they were coded, let me say, in terms of color, was definitely version 1. [...] because it became clear to me here what the buttons were for.” (P250, 95)

Again, personal color preferences impacted whether participants liked or disliked the color schemes. This concerns both versions: the blue-green (“But that’s also a personal thing because with blue and green, you’ve got my two favorite colors.” (P244, 96)) and the gray-orange (“[...] rather adult-looking, boring color scheme [...]” (P244, 97), “mainly simply because I found it the least appealing.” (P250, 98)) color scheme.

For this group, the reduced colorfulness was positively perceived almost throughout. Significantly, the enhanced meaning of colors using corporate design colors was positively mentioned, as was the easier differentiation of content through precise color use. However, the lower colorfulness led to some deficits concerning contrasts that could be improved. Overall, the increased informativeness was a complete success and strongly impacted the UX. Coloring the buttons in the respective particles’ colors severely helped participants obtain an overview and understand relations and categories.

Overall Impact on UX In summary, the adapted versions had a positive impact on the perceived UX for this group. Beneficial are the reduced functionalities, the reduced colorfulness, and the higher informativeness of colors. A negative adaptation observed throughout the group was the reduced level of detail, which most participants did not like to its full extent. However, some appreciated partially reducing the level of detail by using the button in DetailView as it reduced information overload. This UI aspect needs to be carefully adapted and further investigated as it got mixed reviews in this group. Based on the participants’ ratings, version 2 is a clear winner for this group. The combination of the adaptations of reduced functionalities, lower colorfulness, and high informativeness led to this overall good rating. Version 1 also provided a better UI than the baseline version, according to the participants’ ratings. Subsequently, these adapted versions for group 3 successfully improved the UI and its UX with the proposed personalization

approach. Contrary to this qualitative result, the quantitative values of the UEQ-S for this group (Table 7.13) show a decrease in the overall quality for both versions. In particular, the quality of version 1 was rated much worse, with a difference of -0.458 from the overall quality of the baseline version. The difference between version 2 and the baseline was solely -0.042. Looking more into the details, the pragmatic quality of version 2 (1.667) is higher than that of the baseline version (1.417). In contrast, the hedonic quality has declined from 1.333 for the baseline version to 1.000 for version 2. However, the qualitative evaluation and the ratings show that version 2 is the favorite UI for this group. The UEQ-S, in this case, does not clearly confirm this result but rather indicates that the hedonic quality could be improved for a clear UX improvement.

Group 4

The adaptations for all groups are summarized in Table 7.12. All UI aspects have been personalized in either version 1 or version 2 based on the identified intercultural group profiles. Their impact on the UX is analyzed based on the interviews and summarized in the following paragraphs.

Functionalities Version 2 (fairness strategy) adapted the fourth group's functionalities to facilitate more functionalities. Consequently, the buttons for organization and news/content were enabled in this version, and panels with an overview of the corresponding particles were displayed. This leads to easier access to information through more functionalities. Throughout the whole group, this adaptation was very much appreciated. There is no doubt that this new possibility enhanced the UX; participants felt that it was also one of the most helpful adaptations between the versions by mentioning that "(t)he functionality is beating." (P207). Remarkably, the users perceived this new functionality as empowering and enjoyed the new control over the display, the new possibility to more precisely search for content, and to get a more structured overview: "Well, this choosing the... having the choice of news items or institutes, for example. Everything is displayed to me at the same time. [...] That is for me the biggest point." (P207), "The ability to better search for people or better search for information." (P268, 99), "good things were in this two buttons, because they were more structure than this." (P299)

Overall, the added functionalities increased the UX, giving users more control over what they can see and explore. This adaptation is positively impacting the UX. However, it depends on whether the users perceive the functionalities as useful.

Level of Detail For this group, the UI aspect level of detail has been decreased for both adapted versions. The evaluation showed that this adaptation received mixed reviews.

The button in DetailView to separate some basic information from detailed information was mostly perceived as helpful or neutral. Participants reported that it could enable easier exploring of the content and reduced information overload: "But it can also improve the UX if... [...] so that was already hard to scroll and it was very small." (P254, 100), "Better than getting all the texts at once." (P298, 101), "And also having the button, here like this with the picture when I click on

the bubbles that would help me because, for example, if I'm interested to look more I can click." (P299) However, some participants disliked the button as receiving all the information required an additional step. This negative feedback may also result from the implementation quality as it was more of a prototype, and the interaction with the button was very sensitive, which annoyed some participants: "But I still find it more convenient if I can see everything straight away and don't have to open it up." (P288,102)

The most controversial adaptation related to this UI aspect was removing the names of persons and organizational particles. Most group members negatively rated this adaptation and preferred the baseline version that included the names. This adaptation confused the participants as they lost purpose in exploring these particles because it was perceived as not functional anymore: "Yeah, but that's not functional. It makes no sense at all. [...] This is not a modeling agency." (P207), "So that I (can) make the connection between text [...] with this person, then you need a name. [...] the functionality improves when the names are there." (P298, 103) However, visually, some participants liked the version without names: "So visually rather the one without a name." (P268, 104), "I don't find that [name] more appealing. So it's a disruption at first to see that." (P298, 105) During the interview, most group members even mentioned this loss of names as the most disliked adaptation, which shows that these participants did not perceive the advantages of a cleaner UI through this adaptation. With this reduction of text at first sight, participants lost the purpose of interacting with these particles ("Yes, from the people, especially from the people. Because I think that's a bit senseless." (P268, 106)).

In total, reducing the level of detail for this group was only partially successful. The button in DetailView impacted the UX positively by making the interaction easier and reducing information overload. However, it has to be a reliable implementation so participants can fully experience the advantages. The removal of names was a drastic change within this UI aspect and was unsuccessful for the group. Even though some perceived it as more visually appealing, it also reduced the functionality and purpose of these particles. It should be considered that functionality and purpose can be more important than visual appearance concerning this UI aspect.

Density The density for this group has been increased to medium in the second version. Most participants preferred the low density as they perceived the speed of the particles moving more slowly, which made the interaction easier. The higher density was perceived faster and increased difficulties getting an overview of what is displayed: "In the end, I realized that somehow... suddenly so many things came at once. And really, tick-tick-tick, one after the other moved so quickly [...]. " (P298, 107), "[...] and that the bubbles move faster. Maybe it's just my imagination, but I had the feeling that everything was moving faster and I had less time and everything was a bit more hectic." (P254, 108), "[...] that's quite a hustle and bustle. And that was a bit (of a problem for me), because then you're like, ah, that's interesting and that, boah, now it's gone again, oh, where has it gone? " (P288, 109), "I like this one (V1) because it is going slowly, to me." (P299) Coping with medium density, it was mentioned that getting used to the display and the added functionalities with the panels enables more control over the display, which makes higher density more acceptable: "Over time, you get a bit used to it. So maybe it was okay."

(P298, 110), “But basically, I don’t find it that dramatic because I can also have an overview. If it gets really too much for me, then I say, okay, I’ll just take the topics and then I’ll take a look at what’s there. I have the opportunity to do that. Then it’s a bit more relaxed again.” (P288, 111)

The whole group favored the lower density, while a higher density can be acceptable when providing additional functionalities. Also, this UI aspect has to be evaluated in the long run to identify whether getting used to the display positively impacts a higher density and would be perceived as beneficial for the UX.

Content Type In version 1, the content selection focused more on formal content, resulting in more content particles than person and organizational particles. Within this group, a participant noted that the preferences for a balanced content selection or a higher focus on content particles depends on the level of detail: “If I just have the name of the person or no name I would definitely have this version here (V1) because I can immediately tell if it’s going to be interesting for me or not.” (P207) The other participants evaluated this adaptation diversely: Some were neutral, others preferred the more balanced version, and some the more content-focused one (“So always the news. So news to content, news to people and, of course, more content versus people” (P268, 112)). This UI aspect and its adaptation were neither reported in the discussion about the most liked adaptations nor the most disliked ones.

Overall, this UI aspect seems to be the least exciting for this group, and both versions are fine. Interestingly, one participant observed that the level of detail impacted the content type selection. Preference for the number of particles depended on whether participants perceived them as beneficial. If users are not interested in the person particles at all, and the names were removed due to the low level of detail, additionally reducing the number of these particles can result in even fewer interactions with them in the end as there is no need to interact with them as they do not fulfill any purpose or function for the users.

Colorfulness and Informativeness of Colors Both adapted versions featured high informativeness of colors. Additionally, version 2 applied a lower colorfulness using the corporate color design. The opinions on the color scheme were mixed, but the higher informativeness was rated higher than in the baseline version in both cases.

On the positive side for the color scheme of version 2, participants noted that they preferred it (“I like the orange and gray combination.” (P207)), especially because of the reduced amount of colors (they disliked the blue-green color scheme), it improved distinguishing the content, and the use of more neutral colors and background: “Yes, there are too many colors, too many shades of blue.” (P298, 113), “[...] I look at gray as a neutral color.” (P298, 114), “So it was simply, I find these same colors (B/V1) quite terrible. [...] Because you try to find a logic. Then this confusion with this different blue, blue-greenish together.” (P268, 115), “I can relate the symbols for example from the symbol that is in front of the person, [...] I do not need the color differentiation. I just need one orange and one gray, that’s all. And the symbols in front. That’s enough for me.” (P299) Moreover, the color scheme was liked due to the additional meaning of using corporate colors: “[...] I like the fact that it has this scheme from the university.” (P254, 116) To underpin the positive impressions, the gray-orange color scheme was also mentioned

as the most helpful adaptation by some participants, also due to its more neutral background (“I would say the background color and I could like read easily because of the background color.” (P299)) and as it has “a more stringent color coding.” (P268, 117)

For the blue-green version, participants mentioned that it looks more modern to them: “I like this green with the blue background. I like it, it looks very modern.” (P254, 118), “[...] for me it’s also [...] somehow more objective, a bit more scientific, somehow the blue, it reassures me a bit and it seems more serious to me now.” (P288, 119) This color scheme was perceived as more beautiful due to its modern look and feel, and the participant’s personal color preferences.

Most participants found differentiating content easier within version 1 due to its higher color contrast than in version 2. They explained their preference for the blue-green color scheme as follows: “I think in terms of usability version 1 was the easiest for me.” (P207), “I think there is more contrast here (V1). Here you can already see from the color scheme that there are three different content types.” (P254, 120) Other participants preferred the gray-orange color scheme concerning the differentiation of content due to using signal colors for highlighting certain particles: “But if (you) want to focus on the people in the university, then it’s better (V2), that’s the focus. If the news is about research lines, something, then the other way around.” (P298, 121)

Coloring the buttons resulted in mainly positive feedback. However, one participant was confused by the colored buttons in version 2 as the contrasts were low (“[...] for example, this button on the far right, it looks almost orange. So the second one looks almost orange because it has so much orange in it. Then it’s confusing.” (P254, 122), “Yes, yes. I don’t need the legend again, not in color, not colored.” (P254, 123) In total, the others perceived the coloring of the buttons as a positive influence on the UX, which helped them differentiate the content more easily, and reported this adaptation as most helpful (“The functionality, the buttons here (V1/2), so there was a connection of colors, they are content-related.” (P298, 124), “That I now have color differences here (V1, buttons), that I can immediately see what I see there.” (P288, 125)).

Using colors repetitively in DetailView was, on the one hand, positive for the participants (“I like the background, that the background is the same color. Yes, I think that’s positive.” (P254, 126)). On the other hand, it was too colorful for some participants with this repetitive use.

For this group, the reduced colorfulness received partly positive feedback as it was easier to follow what happened on the screen, and the focus was clearly put on the signal colors, which helped differentiate the content. However, the lower colorfulness resulted in fewer contrasts, which was evaluated negatively by others within this group, as content differentiation has suffered from that adaptation. A less colorful scheme hampers achieving suitable contrast, which is necessary to enable a fully positive influence on the UX.

The informativeness of colors was positively adapted and implemented with the colored buttons. This adaptation made differentiation much easier for the users. The repetitive use of colors in the background of the DetailView and the additional meaning of colors by using corporate design colors had mixed reviews and only enhanced the UX for some participants.

Overall Impact on UX Comparing the participants' ratings, which UI version they preferred in total, version 2 was the overall winner, followed by version 1. This clear result shows that the adapted versions beat the baseline version and thus provide an overall better UX. Adapting the UI to the preferences based on the intercultural profile was successful for this group. Remarkably, the adaptations of the UI aspects informativeness of colors and access to functionalities were outstanding and the reason for this positive development. The UEQ-S result for this group (Table 7.13) aligns with this qualitative result. The overall quality of version 1 was +0.687, and for version 2, +1.021, higher than for the baseline version. Both the pragmatic and hedonic qualities have been improved with the adaptations, with version 2 even better than version 1.

8.3.2. Impact of User Interface Aspects on User Experience

This section summarizes the findings for each UI aspect, considering the impressions across groups. It further points out relations and dependencies between UI aspects and how their adaptation impacted the UX.

Functionalities

Reducing access to functionalities by removing buttons was perceived as beneficial by groups 2 and 3 as it positively influenced the UX by simplifying the UI. However, this was only the case because participants were unclear about the purpose of the removed buttons. It was easier for participants to interact with the UI as they did not question the unclear buttons. A solution to add operational buttons, e.g., a refresh button, could be to hide them in a menu as they should not appear at first sight. However, group 4 benefited from more functionalities that empowered the interaction and were strongly positively rated by the participants. They perceived the new functionalities as more advantageous for the interaction, which was decisive for the overall ranking. This goes hand in hand with the other group's reviews, which indicate that functionalities displayed through buttons should be selected carefully and limited to the necessary ones that are a clear advantage for the users. Overall, the adaptation of functionalities had a positive impact on the UX and was, in some cases, decisive for the success of the adapted versions.

Level of Detail

This evaluation reduced the level of detail for groups 2, 3, and 4. There was no evaluation in which the level of detail was increased. The level of detail was reduced in two aspects: (1) the names of persons and organizational particles were removed, and (2) the DetailView was separated by implementing a button that expands and displays additional information if available. The first adaptation, the removal of the names, was controversially discussed and received mixed feedback. While most participants of group 2 perceived the removed names as helpful because this adaptation simplified the UI, they also mentioned that if the display should enable recognizability, this adaptation was not beneficial in this respect. Others, such as groups 3 and 4, rated the removed names as too drastic, describing it as an adaptation that removed the

purpose of displaying those particles. Especially concerning the level of detail, it is necessary to consider that functionality and purpose can be more important than visual appearance. The second adaptation, the button that separated the content in the DetailView, received mainly positive feedback. Most participants perceived it as positively influencing the UX, making the interaction within DetailView easier and reducing information overload.

The adaptations for this UI aspect may not have been perfectly chosen as removing names was too drastic, which led to negative feedback and impact on the UX. However, the other adaptation, the button to separate content in DetailView, was mostly consistently well-rated. This indicates that the reduced level of detail partially improved the UX when focusing on reducing information overload by separating content exposure.

Density

The density was evaluated by changing the maximum number of particles displayed simultaneously in FlowView. Group 1 evaluated all three densities: low, medium, and high. The result shows that the high density negatively impacted the UX, resulting in overall avoidance of this version as participants felt overwhelmed. Groups 1 and 3 mostly rated the medium density as acceptable. Others preferred the version with low density as the density was observed to be related to the perceived speed of the particles in FlowView, which was, for some participants, too fast when increasing this UI aspect. Additionally, the evaluation revealed that density and whether it is perceived as having a good impact on the UX are related to other UI aspects: level of detail, content type, colorfulness, and available functionalities. This increases the complexity of selecting the right amount of particles, which can be found as a result in most evaluations. However, group 2 was prominent as the density was the same in all three UI versions, but the other UI aspects were adapted. Thus, it revealed dependencies on other UI aspects. The relations to other UI aspects can be summarized as follows:

- **Level of Detail:** Reducing the level of detail by removing names reduces the amount of text users need to read or “skim.” This makes higher density more acceptable.
- **Content type:** Focusing on more content particles results in having more particles with more text, which increases the amount of text a user needs to read or “skim.” This makes higher density less comfortable.
- **Colorfulness:** Using fewer colors results in applying colors only for specific content. This enables the user to focus more easily on selected particles and cut out others, which makes higher density more comfortable.
- **Functionalities:** Providing more functionalities that allow users to search content in a more targeted way helps users manage information overload through higher density as they can search for it more precisely.

Due to its complexity and dependency on other UI aspects, density adaptations within the personalization approach were unsuccessful in improving the display’s UX. This UI aspect would

benefit from user involvement, allowing them to more easily adjust the UI and, consequently, increase their individual UX. Also, evaluating this UI aspect in a longitudinal field study may reveal whether familiarity with the display influences density preferences.

Content Type

The adaptations evaluated in this study shifted towards a more formal version, which included and displayed more content particles, and a version that included particles with information about social activities. Overall, both adaptations were rated as good improvements for the UX. The first group benefited from more social activities displayed at the display, which was mentioned as one of the most helpful adaptations. Users gained awareness about what was happening besides formal achievements, making exploring content more engaging. Many participants of groups 2, 3, and 4 also preferred the other version, which included more or mainly formal particles. This was due to the unclear purpose of person particles as most study participants are not working in that department, and recognizability was impossible for them. This made person particles irrelevant and content particles much more enjoyable. Thus, the shift towards more content particles was preferred as the irrelevant particles were reduced, which made the interaction with the display intriguing. However, changing the target group, the context of the display location, or how people are displayed, e.g., using keywords from their field of expertise, may change this adaptation's assessment. Considering the participants' feedback, this UI aspect did not necessarily impact their decision of whether they liked or disliked a UI version. However, the adaptations were generally rated very well and positively affected their UX, which symbolizes that considering the intercultural group values mostly matched the group's preferences. Moreover, it must be considered that the unclear purpose of some content and the missing recognizability may have impacted the success of the content type adaptations.

Colorfulness & Informativeness of Colors

The colorfulness was evaluated as medium and low by all groups. The informativeness of colors was raised to high for all groups and medium in version 1 for group 3. The higher informativeness of colors, medium or high, consistently received positive feedback from all participants and strongly influenced the UX. Increasing the informativeness of colors supports users in getting an overview and enables them to differentiate content more easily. This was achieved by coloring the buttons as a legend to relate the flying particles from the FlowView to the buttons. The repetitive use of colors in DetailView received mixed reviews, with a rather low impact on the UX. However, in correlation with the low colorfulness, some UI versions switched to a corporate design color scheme in gray-orange, which, concerning the informativeness of colors, was a clear success in improving the UX. Most participants appreciated this additional meaning of colors, providing them with a UI in a more professional layout. This reduced colorfulness led to the precise use of the colors available; in this case, it was an intense orange, which further increased the informativeness of colors. It was even easier to differentiate content types using this signal color on a specific content type that should stand out. However, some participants

had a personal aversion to the gray-orange color scheme, but the advantages of the colors' informativeness, easier content differentiation, and corporate design outweigh these negative aspects. The UI versions with low colorfulness were implemented by using many shades of gray and one orange color as in these versions, the informativeness of colors was supposed to be high (thus, additional meaning was achieved by applying the corporate design). However, this limited selection of colors led to lower contrasts that negatively impacted the UX. This was partially criticized by a few participants, but can be solved by changing the implementation to stronger contrasts between the shades of gray and how they are combined with orange and the background. However, it must be considered that the few colors available for such a low colorfulness UI must be selected carefully as contrasts are still required for good UX. Additionally, the colors used, e.g., in our case, the orange, are more highlighting, which draws the user's attention to the objects that the color is applied to, which means the purpose of the display and what the users should focus more or less on is an essential design decision. In total, adapting the UI aspect informativeness of colors has an apparent positive influence on the UX, while adapting the UI aspect colorfulness improved the UX in most cases.

8.3.3. Summary and Discussion

This section summarizes the overall findings concerning whether and to what extent the adaptation of the UI aspects influenced the UX. Additionally, the gathered quantitative data from the UEQ-S is summarized across the groups to identify what was more or less impacted by the intercultural adaptations.

UX Findings

Reviewing the overall ratings across groups, version 2 received more positive feedback, and participants reported that the adaptations strongly impacted their UX. Interestingly, in many cases, the overall preference for a UI version depends on whether the participants liked one specific adaptation of a UI aspect much more or vice versa. Outstanding adaptations that positively impacted the UX were the following: higher informativeness of colors, reduced colorfulness, change of content type (including social activities and more formal content), lower level of detail in DetailView, and reduced or increased access to functionalities. The adaptations concerning density have turned out to be much more complex as many other UI aspects impact the success or failure of it. However, high density had a clear negative impact on the UX, while medium density had little to no negative effect, depending on other UI aspects.

UEQ-S

Analyzing the quantitative results of the UEQ-S across groups, this measurement underpins and indicates which UX criteria are most impacted by the intercultural adaptations. Version 2 improved the overall quality for most groups (not for group 3). Version 1 also improved the overall quality for groups 2 and 4, but the improvement was always lower than with version 2.

Distinguishing the result into analyzing the pragmatic and hedonic quality changes, it could be observed that if there was an improvement, it was mainly apparent in the pragmatic quality. In contrast, the hedonic quality declined in all groups besides group 4. All 24 participants evaluated the baseline UI with the UEQ-S, but only six completed the questionnaire for each adapted version. Therefore, the results are not solely reliable and can only indicate that intercultural adaptation may positively impact pragmatic quality and, in most cases, negatively impact hedonic quality. Nonetheless, the positive impact on pragmatic quality leads to a higher overall quality in most cases (concerning version 2). This suggests that this personalization approach may be more effective at improving pragmatic quality than hedonic aspects of the UX. While other personal preference factors may more strongly impact these hedonic values, cultural values do not necessarily affect them positively. Another underlying cause leading to this result could be the study design, as the hedonic items target, for example, the novelty of the UI, which naturally decreases with interaction time and is reflected in lower user ratings after longer interactions, such as during the on-site evaluation. However, this should be further investigated in future research projects.

Part IV.

Research Findings and Conclusion

9. Intercultural Personalized User Interface Design

This chapter summarizes the key insights from evaluating the personalization approach through an application-specific implementation for CommunityMirrors. Based on the findings, improvements for the approach proposed in Chapter 5 are identified. Additionally, limitations are discussed that need to be considered for an in-depth understanding of this work.

9.1. Summary of Findings

Based on the evaluation, the approach identified (Chapter 5) for personalizing large interactive displays for intercultural groups in semi-public areas was exemplarily transferred to the CommunityMirror application. This application fosters knowledge exchange by displaying content following the serendipity principle in semi-public areas of the Computer Science department of the University of the Bundeswehr Munich. For this application, an evaluation with 24 participants, divided into four groups with six participants each, was conducted in a laboratory setting, applying a mixed methods approach with a stronger focus on qualitative data. The objectives were to verify the overall proposed approach of personalizing such a large interactive display in semi-public areas for intercultural groups and to derive answers to open questions that remained within the approach's development phase. The open questions were:

1. **Group Modeling:** Which aggregation strategy for merging cultural user profiles results in a better group profile, representing the intercultural design preferences of the group?
2. **Impact on UX:** What was the effect of personalizing UI aspects through adaptations on the UX?
3. **Personalization Approach Validation:** Does the approach consider all relevant aspects for personalizing a large interactive display for intercultural groups in semi-public areas?

Based on the evaluation, the following answers were determined:

Group Modeling When comparing the UI versions derived based on the aggregation strategy applied, the average without misery or fairness, it became apparent that the UI version based on the intercultural group profile calculated with fairness strategy was more successful than the UI version based on the intercultural group profile calculated with average without misery. A negative factor impacting the success of the average without misery strategy was the threshold

of +/-10, which led to ignoring too many values within the group, resulting in misery for most group members. Consequently, it can be concluded that it is essential to consider all values when aggregating cultural profiles.

Leave no one out.

Consider all cultural profiles within a group equally; cultural dimension values in the middle, around 50, are equally vital.

The order in which participants selected their most important cultural dimension value partially negatively impacted the success of the fairness strategy. Moreover, if more participants in the group had a similar cultural profile, meaning they were more homogeneous, it was advantageous for the outcome, as more suitable design preferences were selected for these participants than for others. However, despite these impact factors, the UI versions derived with the fairness strategy were positively rated throughout.

Everyone gets at least one.

The concept of fairness, selecting for every group member at least one suitable value ("item"), is a successful strategy, while *order* may negatively and *homogeneity* may positively impact the outcome.

Overall, the strategy fairness resulted in UI versions preferred by the participants throughout all groups. The average without misery was not satisfying for most participants. However, it still derived a better UI design than the baseline UI, which did not consider intercultural preferences. Unless additional evaluations compare other aggregation strategies and reveal new insights into their suitability in this context, the recommendation derived from this evaluation is to use the fairness strategy for aggregating cultural user profiles.

Impact on UX The personalization of the UI aspects based on the group's profiles led to an improved UX, especially with version 2, where the fairness strategy was applied. While the adaptation (no user involvement) as personalization was successful for most UI aspects, it was unsuccessful for the UI aspect density. The evaluation revealed that dependencies on almost all other UI aspects strongly impacted the perception of density. In most cases, the users were not satisfied with this UI aspect, which increases the complexity of autonomously adapting it. Consequently, it would be recommended to increase the user involvement for this UI aspect to match the user's preferences more easily by customizing it directly during an interaction.

Leave control when there are too many dependencies.

User involvement should be increased when a UI aspect's perception, in this case, density, is impacted by many other UI aspects.

Based on the UEQ-S result, the evaluation revealed that the personalization for intercultural groups mainly positively impacted the pragmatic quality, especially with version 2 (fairness strategy), but in some cases, negatively impacted the hedonic quality. However, the improvement in pragmatic quality increased in almost all groups the overall perceived quality as measured by the UEQ-S. The impact factors leading to this result remain unclear and must be investigated further. Overall, the intercultural personalization approach for the UI of large interactive displays was still successful.

Pragmatic quality in the focus.

The intercultural personalization of large interactive displays revealed a strong positive impact on the interaction's pragmatic quality.

Personalization Approach Validation The evaluation revealed a successful implementation of the overall personalization approach for the UI of large interactive displays used by intercultural groups. During the validation, no missing aspects appeared, displaying that all relevant factors were considered in the approach. Reviewing all requirements, all nine were considered:

- **REQ1:** Minimize user involvement. The user model used to calculate the cultural user profile was reduced to gathering only the data required to adapt the key UI aspects. Also, the focus of the overall approach was on adaptivity, which means no user involvement as the system itself decides what should be changed and how. However, it was identified that the UI aspect density would benefit from user involvement due to its many dependencies with other UI aspects, and thus, it should be customizable. This leads to as little user involvement as possible for a successful personalization approach.
- **REQ2:** Ensure a comprehensive approach by selecting a UI aspect from each design paradigm to consider various perspectives on personalization. This is fulfilled as the six key UI aspects cover each of the four design paradigms [50] with a slightly stronger focus on architectural design.
- **REQ3:** Focus on personalizing the key UI aspects identified. Throughout the process, data acquisition, etc., the focus was solely on the key UI aspects and on no other parts. Comments and feedback about other UI elements were ignored when interpreting and analyzing the data, which was gathered during the evaluation.
- **REQ4:** A prioritization is required in case a UI aspect is related to multiple cultural dimensions. For this requirement, the Borda count was selected to identify the most important cultural dimension based on the user profiles within a group. This ranking is then used to prioritize adaptation rules if a UI aspect is related to several cultural dimensions.
- **REQ5:** The adaptation degrees must align with the personalization objective. The degrees chosen and evaluated were low, medium, and high, and were suitably selected as they enabled detailed personalization for each group.

- **REQ6:** The personalization approach must allow for application-specific adaptation rules that refine the general adaptation rules. With the help of an expert workshop, the general adaptation rules were interpreted for the CommunityMirror application. These adaptations were successful in most cases. However, an adaptation concerning the level of detail, removing names from FlowView, was too drastic and could have been less immersive.
- **REQ7:** All necessary information about each user of the intercultural group must be collected to generate an accurate cultural user model. As the evaluation was in a laboratory setting, the users were randomly assigned to groups, and the data was collected through an online survey, focusing only on the required information, data minimization, according to the personalization of the UI aspects, and whether the information was necessary to calculate the cultural dimension values.
- **REQ8:** The calculation of the cultural user model must be updated to incorporate all relevant user-provided information. The calculation of the cultural profiles was expanded by considering the user's nationalities and, if submitted by the user, the parents' nationalities and political orientation.
- **REQ9:** The personalization approach must support the most suitable group modeling strategies for all necessary calculations. The strategies' average without misery and fairness were compared by evaluating the two resulting UI versions using qualitative and quantitative methods. The result showed that fairness is so far the most suitable aggregation strategy.

The personalization approach was implemented and evaluated in-depth, revealing a successful strategy for interculturally personalizing large interactive displays. The following section updates the previously promoted approach (Chapter 5) by considering the evaluation findings.

9.2. The Personalization Approach: Iterative Improvement

Based on the evaluation, the findings show that the following answers lead to these improvements for the proposed procedure (Section 5.1) as part of the personalization approach:

- **Group Modeling:** The fairness strategy is most suitable for aggregating the cultural user profiles.
- **Impact on UX:** The users should be involved when personalizing the UI aspect density as it has too many dependencies with other UI aspects. The adaptation of the different UI aspects positively impacted the UX.
- **Personalization Approach Validation:** Overall, the personalization was successful. After answering the open questions, the verification and evaluation of the UI versions could be expanded by incorporating user feedback or analyzing interaction data to verify the suitability of the design. The application-specific implementation provided an example of an extensive UX evaluation applying qualitative and quantitative methods.

Based on these insights, the changes within the approach and its procedure can be summarized as follows:

1. **Acquisition & Cultural User Modeling:** Using a survey to collect the necessary information about the users for calculating the cultural user profile is a successful tool.
2. **Group Modeling:** Use the Borda count strategy to rank cultural dimensions and the fairness strategy for aggregating values for each cultural dimension.
3. **Identification of UI Adaptations:** Consider involving the users in customizing the UI aspect density. This user involvement leads to another degree of personalization, but is necessary for a positive UX due to the UI aspects' many interdependencies with others.
4. **Group-Specific UI Implementation:** Adjust and implement the UI version to achieve a group-specific UI while also considering the different types of user involvement for the UI aspect density here.
5. **Verification & Evaluation:** Incorporating user feedback or analyzing interaction data as part of the application's operational management further verifies and improves the UI, which can be of various extents.

The ontologies and system architecture were proven helpful in depicting relevant aspects, components, and their relationships.

9.3. Limitations

While this work promotes interesting findings regarding the intercultural personalization of large interactive displays, the approach proposed and the evaluation conducted have some limitations, which are summarized here.

Evaluation The evaluation exemplified the personalization approach for the CommunityMirrors application. The laboratory setting reduced the complexity of implementing this approach in field deployments, as the users were directly identified after they signed up for the study. In a field deployment, this aspect strongly depends on the work environment and the location of the display. Nevertheless, user identification and collecting data about their cultural background are vital for the personalization objective. Another point limiting this research's results is the number of users merged in a group. Due to the stronger methodological focus on qualitative methods, the group merged solely six users, which is not a high number when interpreting the quantitative UEQ-S result. Consequently, the UEQ-S result can only indicate findings. However, when analyzing group modeling strategies and looking at other group modeling evaluations in research [146, p. 397], merging six user profiles is representative as many others merged fewer for comparing aggregation strategies. Unfortunately, the ranking for group 1 in the evaluation was computed wrong, resulting in the opposite ranking. However, as it does not affect all six UI aspects and the aggregation strategies' results remain the same and represent the group's preferences, the group's ratings and results are still valid for the study.

Personalization Approach A prerequisite for the successful implementation of the approach is user identification. This requirement is difficult to achieve, especially in ubiquitous areas. However, restricting it to semi-public ones enables this requirement by analyzing the surroundings. The systematic literature review, which derived the key UI aspects based on their frequency used in sample applications for large interactive displays, did not consider the application's use case or type. Based on the application's type, e.g., a game, other UI aspects might have been more relevant for investigating adaptations. However, focusing on the UI aspects most frequently apparent in the UI design of large interactive displays leads to a personalization approach most designers and researchers can benefit from. In addition, the approach assumes design preferences based on cultural dimension values. However, other aspects, such as age, gender, or profession, could also impact the design preferences, which depend on the individuals, though those were not considered in this thesis.

10. Conclusion

This work developed an approach that integrated various perspectives on personalizing the UI of large interactive displays for intercultural groups in semi-public areas. First, the personalization approach and findings from its evaluation are summarized. Second, the contribution, its implications, and future work are highlighted.

10.1. Summary

This thesis has developed and evaluated an approach for personalizing the UI design of a large interactive display for intercultural groups in semi-public areas. As discussed, cultural differences in the perception of technology significantly impact its use. The more the UI or product is tailored to the users' preferences, the better it is perceived. Personalizing a UI to a single user and considering their cultural background has proven successful, especially in improving usability and UX. However, shared UIs in semi-public areas target a group of users, making UI personalization a more complex yet significant challenge. This work addresses this gap by contributing a structured approach incorporating various personalization perspectives and validating it through an application-specific implementation to assess its effectiveness. It targets the overarching research question: *“How can intercultural preferences regarding the UI design of large interactive displays in semi-public areas be considered, and how does that impact the user experience?”* To achieve this, the research followed the Design Science methodology by Peffers et al. [178] as a comprehensive framework. Following this method, the determined approach for intercultural personalization of large interactive displays in semi-public areas consists of these components:

- A group modeling ontology for merging multiple cultural user profiles.
- A UI adaptation ontology defines how six key UI aspects of large interactive displays can be adapted according to a particular intercultural group profile.
- A system architecture that integrates all relevant components and their relations is vital for the personalization approach.
- A five-step procedure guiding the systematic implementation of the personalization approach.

The following part briefly outlines the five-step procedure (visualized in Figure 5.1), highlighting the key objectives of each step:

1. **Acquisition & Cultural User Modeling:** Identify ordinary users in the vicinity of the large interactive display, which are then assumed to be frequent users. Collect the necessary information about them using a survey to calculate the cultural user profile (Subsection 5.1.1). As a result, several cultural user profiles with values for Hofstede's six cultural dimensions [87, 89, 90] are identified.
2. **Group Modeling:** Aggregate the previously identified cultural user profiles and determine an intercultural group profile. This includes ranking cultural dimensions using Borda count and the actual aggregated values for each cultural dimension of Hofstede using the fairness strategy (computation described in Subsection 5.1.2).
3. **Identification of UI Adaptations:** Derive application-specific adaptation rules by transferring the general adaptation rules for the six key UI aspects. Combine the previously identified group profile with the application-specific adaptation rules and identify group-specific design preferences. Derive UI adaptations relevant to the intercultural group profile by comparing the current UI design to the group's design preferences and identifying necessary adjustments (Subsection 5.1.3), considering that users should be involved in customizing the UI aspect density.
4. **Group-Specific UI Implementation:** Adjust, implement, and deploy the UI version to achieve a group-specific UI while considering the necessary user involvement for the UI aspect density (Subsection 5.1.4).
5. **Verification & Evaluation:** The personalized UI design must be regularly reviewed and improved to ensure it fits the group and meets their preferences, which strongly depends on various contextual variables (Subsection 5.1.5). Certain events can lead to repeated procedure execution to derive an up-to-date, personalized UI version. Incorporating user feedback or analyzing interaction data as part of the application's operational management further verifies and improves the UI, which can be of various extents.

In addition to the step-by-step procedure for implementing the personalization approach, it is also beneficial to use the ontologies (Section 5.2) as an overview and to obtain an in-depth understanding of all relevant aspects of the personalization objective. Moreover, the system architecture (Section 5.3) offers a holistic view of all key components and their interconnections, further supporting the implementation of an adaptive system.

Demonstrating the implementation of this personalization approach for the CommunityMirror application and its extensive evaluation revealed several findings relevant to answering the posed research questions. These insights are presented in the following paragraphs.

RQ1: Which aggregation strategy is suitable to model intercultural group preferences regarding UI design?

Several group modeling strategies used in group recommender systems to aggregate user preferences were analyzed for this research question. The two most promising ones, average without misery (threshold of ± 10) and fairness, were evaluated in a laboratory setting. The evaluation applied average without misery and fairness to derive intercultural group profiles and identify UI versions tailored to the group's preferences for four groups, each with six participants. An on-site evaluation using think-aloud, UEQ-S, and semi-structured interviews delivered insights regarding which UI version the participants preferred. Therefore, they explored three different UI versions: the baseline UI, which was not tailored to the group and for all participants the same; version 1, which was derived for every group by considering the intercultural group profile calculated using the average without misery strategy; and version 2, which was tailored to the intercultural group profile calculated with the fairness strategy. Based on the evaluation, UI version 2 (fairness strategy) was most often ranked first and, consequently, most successful in merging cultural user profiles. The fairness strategy sequentially selects a value for each cultural dimension from each user profile by considering the most strongly pronounced one. Also, the average without misery approach outperformed the non-personalized baseline UI. However, the threshold of ± 10 resulted in misery by ignoring too many preferences in the group. Overall, these insights were derived concerning the group modeling:

- **Leave no one out.** Consider all cultural profiles within a group equally; cultural dimension values in the middle, around 50, are equally vital.
- **Everyone gets at least one.** The concept of fairness, selecting for every group member at least one suitable value ("item"), is a successful strategy, while *order* may negatively and *homogeneity* may positively impact the outcome.

RQ2: What are key UI aspects of large interactive displays in semi-public areas most relevant for intercultural personalization, and how should they be personalized?

Based on existing literature, cultural differences in UI design were summarized and represent the cultural design preferences based on Hofstede's cultural dimension values. By analyzing these differences, 15 UI aspects have been identified as relevant for the cultural UI personalization. To enable a focus on key UI aspects, a systematic literature review, following the approach of Vom Brocke et al. [237], analyzed 68 application examples for large interactive displays and whether the 15 UI aspects are equally relevant for such displays. As a result, these six UI aspects have been identified as most prominent in applications for large interactive displays: functionalities, level of detail, density, content type, colorfulness, and informativeness of colors. Investigating their personalization potential is most beneficial for researchers and designers.

These six key UI aspects could be matched with Hofstede's cultural dimensions, based on the previously identified cultural differences of UI design, deriving general adaptation rules with high and low adaptation degrees. For the evaluation, these adaptation rules were transferred to the CommunityMirrors application. Therefore, the adaptation degrees were expanded to low, medium, and high for a more precise personalization. After identifying the suitable adaptations

based on the intercultural group profile, the UI versions were evaluated and discussed with a mixed method approach, using qualitative methods, think-aloud and semi-structured interviews, and the UEQ-S as a quantitative method after each UI exploration. A coding analysis of the collected data (transcripts of over 18 hours of audio and video material [223]) revealed that the personalization focusing on adaptation was primarily successful and positively impacted the UX. However, the perception of the UI aspect density was strongly affected by most other UI aspects, which revealed that the adaptation as a personalization degree, which requires no user involvement, should not be recommended in this case. Consequently, user involvement to enable customization is necessary if a UI aspect depends on many other factors.

Assessing the UEQ-S result, besides the overall quality, especially the pragmatic quality, could be improved by personalizing the key UI aspects. Also, the tailored versions were appreciated and ranked higher by almost all participants throughout the evaluation. In sum, the following insights were derived regarding the impact on the UX of the personalization approach:

- **Leave control when there are too many dependencies.** User involvement should be increased when a UI aspect's perception, in this case, density, is impacted by many other UI aspects.
- **Pragmatic quality in the focus.** The intercultural personalization of large interactive displays revealed a strong positive impact on the interaction's pragmatic quality.

10.2. Contributions and Implications

This work contributes to research and practice in HCI, a vital part of Computer Science, particularly in adaptive systems and the design of large interactive displays in ubiquitous areas. The following sections summarize the key research contributions, practical implications, and how the findings can be transferred. Finally, significant scenarios outline the implementation of the personalization approach in real-world examples.

10.2.1. Research Contributions

HCI research investigates interactions with technical devices and benefits from this work's findings on how intercultural personalization can enhance the UX of large interactive displays. This thesis provides the following key contributions to HCI research:

- **Personalization Approach of Shared UI:** Developed and evaluated an approach for intercultural UI personalization in multi-user settings, addressing a gap in adaptive UI for shared interfaces. This contributes to research on adaptive systems, personalization, and the UX design of ubiquitous technologies, particularly semi-public displays.
- **Intercultural Group Modeling:** Determined fairness as a successful strategy for merging individual cultural user profiles and deriving an intercultural group profile, crucial for UI personalization. This contributes to research on group modeling preferences, a vital part of group recommender systems.

- **Identification of Key UI Aspects of Large Interactive Displays:** Systematically identified six key culturally relevant UI aspects, most common in applications for large interactive displays, and developed a personalization approach focusing on them. General adaptation rules were determined by mapping them to Hofstede's cultural dimensions. This contributes to research on UI/UX design, (inter)cultural UI design, and large interactive displays.
- **Trade-Off Between Adaptation and Adaptability:** Adaptation is not always beneficial if the targeted UI aspect has strong interdependencies with others because such UI aspects require user involvement. This contributes to personalization, adaptive systems, as well as interaction and UX design research.
- **Ontology-Based UI Adaptation Approach:** Developed two ontologies (group modeling and UI adaptation) and a system architecture that provides a systematic overview for implementing UI personalization of large interactive displays. This contributes to research on knowledge representation, ontology-based personalization, and artificial intelligent adaptive systems.
- **Application-Specific UI Personalization:** The real-world implementation and evaluation of the personalization approach demonstrated its effectiveness, significantly improving the UX, particularly in pragmatic quality. This contributes to research on empirical HCI, usability and UX evaluations of ubiquitous devices, and developing adaptive systems.

The following paragraphs highlight this work's contributions to each research field related to HCI.

UI/UX Researchers This thesis provides in-depth insights into how considering the intercultural design preferences of a small group improves the UX with large interactive displays in semi-public areas. The evaluation revealed profound findings for UX researchers interested in intercultural UI design, emphasizing how to address cultural differences in shared UI experiences.

Adaptive Systems & Personalization Researchers The personalization approach demonstrated a fully adaptive UI. However, the evaluation revealed that user involvement is required in cases of strong UI interdependencies. Personalization researchers benefit from these findings on adaptation vs. adaptability, helping them determine when user involvement is needed in personalized UI design. Researchers in adaptive systems benefit from the developed ontologies and system architecture as they focus on applications for large interactive displays and consider common challenges in this context.

Group Modeling & Group Recommender Systems This thesis transfers the eleven most known aggregation strategies for group modeling from numerical rating-based values to cultural dimension values, considering their unique characteristics. Researchers investigating the effectiveness of various group modeling strategies can benefit from this extension as it distinguishes group modeling strategies into suitable ones for ranking cultural dimensions and for aggregating cultural dimension values. Moreover, the exemplary implementation and comparison of two

aggregation strategies, average without misery and fairness, is an example of high interest for group modeling researchers, and it was found that fairness is the most successful strategy. Its detailed calculation substantially contributes to this field. Also, this work integrates group modeling with UI adaptation, providing a foundation for future group recommender systems that aim to generate UI design recommendations based on intercultural group profiles.

Ubiquitous Computing This work contributes to ubiquitous computing by developing a personalization approach for large interactive displays in semi-public areas. Researchers of such technology, e.g., smart cities, digital workplaces, etc., benefit from this work's findings, which highlight how intercultural personalization influences the UX of ubiquitous technologies and how adaptive UI design can be applied to shared, multi-user UI in dynamic environments.

10.2.2. Practical Implications

From the practitioners' perspective, this research outcome benefits designers, users, and operators of large interactive displays. **Designers** of large interactive displays can use this work's results to create (inter)culturally sensitive UI. It supports design decisions by considering the cultural diversity of a user group. Also, it is a tool to reduce the unconscious bias of the designer's cultural background, which can impact design choices. The **users** of large interactive displays benefit from this result as it considers their deeply based cultural preferences for UI design and thus increases their UX. This leads to more enjoyable and easier interactions, which also benefits the **operators** of such systems as the personalized UI and improved UX lead to higher interaction rates. Suppose the overall objective of such large interactive displays is to enhance and foster knowledge exchange by increasing awareness for the overall department; higher interaction implicitly can also lead to increased knowledge exchange. Consequently, the enhanced UX leads to more interactions, which fosters knowledge exchange that positively impacts the **company's** success.

10.2.3. Transfer of Findings

The proposed approach to personalizing large interactive displays can be transferred to other scenarios or devices with shared UI. Within many currently strongly researched technologies, e.g., VR, XR, and augmented reality, there are elements or areas of the UI that several users share. Such scenarios benefit from this work's findings, enabling designers and researchers to create an intercultural sensitive UI by merging users' culturally based design preferences. The detailed explanation and determination of the group modeling strategy fairness can be transferred to many other scenarios, where cultural user profiles are merged to obtain an intercultural group profile representing the preferences of all group members.

The selected UI aspects and adaptations target large interactive displays in semi-public areas, but the general adaptation rules must still be refined for specific applications. An example of this is provided within the application-specific implementation of the personalization approach, where expert workshops were conducted to derive application-specific adaptations. Transferring

this approach to other devices requires considering their unique features, such as multimodality. Other UI aspects could become more relevant and should be included, leading to a broader adaptation table that considers other cultural dimensions, expanding this work's contribution.

Within group recommender systems or the group modeling subtopic, the insights regarding group modeling intercultural group profiles are interesting as they provide an example of using cultural dimension values for aggregation rather than typical numeric ratings. Parts of the elaborated fairness calculation, for example, damage calculation, can also be transferred to aggregating traditional numeric ratings, with minor adjustments to calculating the differences between one user and the others within the group.

While this personalization approach requires identifying users to compute their cultural profile, using personas is an alternative for more public settings with larger or unknown user groups. Such personas are created by collecting exemplary user characteristics that represent a specific segment of the target group, focusing on cultural backgrounds. They represent users with similar cultural profiles and can be used in the subsequent steps of the personalization approach. Fieldwork is required to identify such personas, e.g., through surveys. A student's project (see Figure 10.1) conducted such an example of data collection by promoting a brief survey on a large interactive display in a semi-public area and asking users to provide information about their nationalities, previous residences, language skills, etc. However, information concerning data privacy, such as names, age, etc., was not asked due to the exposed location, the semi-public area. Thus, the cultural user profile calculation proposed in this work is not applicable and must be redesigned. Another idea is to promote an online survey available through a QR code on that large interactive display, with additional information about how often the user is near the display's surroundings. This would help select the order for fairness group modeling by weighting the importance of the cultural user profiles for the group profile.

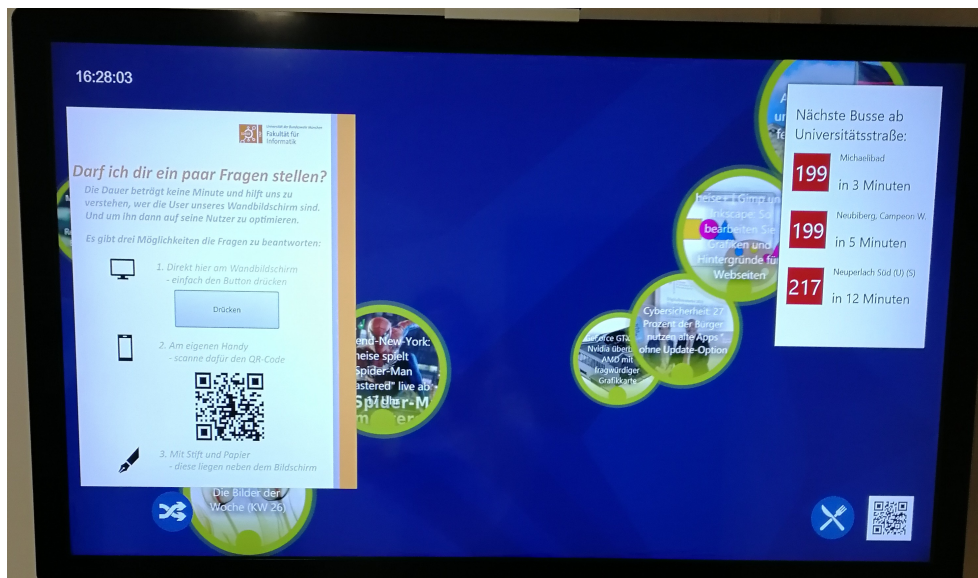


Figure 10.1.: Example set up by students to gather information about the cultural background of large interactive display users in a semi-public area.

Scenarios for Real-World Application

This part depicts potential scenarios where this work's results can be used. This includes discussing transferring the personalization approach to companies with desk-sharing environments, intercultural research projects, and shared spaces in VR.

New Ways of Working: Companies Introduce Desk Sharing As part of the “New Ways of Working” [43], the conception of office usage has changed. It has become popular to reduce office space, save costs, and introduce desk sharing [56, 245] among the employees to use it more efficiently. Some companies have implemented an approach that requires employees to book one of these shared desks if they want to come to work. Consequently, such a booking system already provides information about who is sitting where, including the employee's personal information. Incorporating employees' data about their cultural background would enable daily adaptation of large interactive displays deployed in such areas. Focusing on knowledge exchange, interactive displays could be used as information radiators that share information about the people working in that area that day and the topics they are working on. Adapting the design to the group's intercultural design preferences enhances the UX and increases the interaction. Also, if the bookings change daily, the UI would change daily. On the one hand, this would automatically trigger the novelty effect [117], which means that the employees would be curious about what is new with the display design every day, resulting in higher interactions. On the other hand, it could confuse users as to why a specific UI design has been selected. To counteract this point, an explanation of the derived UI design would be required to reduce this impact and make it more reasonable and acceptable for the users.

Intercultural Research Projects Research in rural areas or other countries automatically leads to intercultural research groups. In the case of developing technological artifacts in such projects, this thesis approach can be applied to enhance the research group's understanding of cultural differences and reduce the negative impact a UI design can have on the target group's perception. By considering cultural differences beforehand, researchers and designers can create a more culture-sensitive design and thus reduce the unconscious bias that would hamper their research results.

Shared Spaces in VR Personalizing a shared area within VR is another potential application area for transferring this work's approach. For example, office workers can use VR as virtual meeting rooms, collaborative design platforms, serious games for training, or social applications. In such environments, multiple users from different cultural backgrounds interact and share virtual spaces, making personalizing shared interfaces highly relevant. The personalization approach developed in this thesis could be beneficial for merging cultural user profiles and deriving general adaptation rules pertinent to UI design. However, the UI adaptation and the focus on certain UI aspects may differ from the proposed approach as shared spaces in VR may encounter other, more prevalent UI aspects (e.g., multimodal interactions, visualizations, and user tracking).

10.3. Future Work

While this work proposes an approach to intercultural personalization, this section summarizes additional steps that can build upon this work's outcome.

The personalization approach was evaluated in a laboratory setting. Future research should investigate the real-world impact of intercultural personalization in field settings, particularly regarding long-term engagement with dynamically evolving group profiles. Also, it would be interesting to investigate the possibility of adding user feedback loops to enhance and improve the UI further. This additional aspect is not specified in this work. Still, it would improve the derivation of UI recommendations for groups and make the approach more intelligent by considering other groups' ratings and incorporating user feedback directly to evaluate the UI versions. In detail, methods of group recommender systems could be applied to derive more precise UI design recommendations based on, e.g., collaborative filtering. Moreover, the group modeling strategies could be further expanded by considering the satisfaction of group members when deciding on a cultural dimension value.

In addition, the results from UEQ-S are interesting but could be further elaborated. Since the hedonic quality of the personalized UI decreased in some cases, it would be interesting to investigate the reasons and countermeasures.

Additionally, the previous section elaborated on how these research outcomes can be transferred, which motivates further extension and improvements of the current personalization approach for future research projects. Depending on other devices and contexts, highlighting other UI aspects can be required, expanding this work's personalization approach.

10.4. Closing Remarks

Our cultural background impacts design decisions, often an unconscious bias [220]. This work develops an approach to derive design preferences for a group by merging individuals' cultural user profiles using the fairness strategy. With this approach, the unconscious bias can be reduced, and the UI design of large interactive displays in semi-public areas can be personalized for intercultural groups. This work contributes to personalization and group modeling research by transferring group modeling strategies to cultural dimension values and comparing two approaches in detail. Also, identifying the key UI aspects of large interactive displays and their cultural differences in design preferences is a vital contribution. Additionally, implementing the personalization approach for the UI design of large interactive displays in semi-public areas to a group's intercultural design preferences positively impacted the UX, proving its importance and effectiveness. This demonstrates that cultural influence on UX is profound. Considering this impact benefits all parties involved in the design, development, and deployment of such devices.

Appendix

A. Cultural Dimension Values by Hofstede

Table A.1.: Hofstede's cultural dimension values for all countries maintained by [68]. Data retrieved in July 2024 from The Culture Factor Group.

Country	PD	IDV	MAS	UA	LTO	IND
Albania	90	27	80	70	56	15
Algeria	80	29	35	70	25	32
Angola	83	18	20	60	15	83
Argentina	49	51	56	86	29	62
Armenia	85	17	50	88	38	25
Australia	38	73	61	51	56	71
Austria	11	77	79	70	47	63
Azerbaijan	85	28	50	88	59	22
Bangladesh	80	5	55	60	38	20
Belarus	95	48	20	95	53	15
Belgium	65	81	54	94	61	57
Bhutan	94	52	32	28		
Bolivia	78	23	42	87	21	46
Bosnia and Herzegovina	90	40	48	87	36	44
Brazil	69	36	49	76	28	59
Bulgaria	70	50	40	85	51	16
Burkina Faso	70	15	50	55	27	18
Canada	39	72	52	48	54	68
Cape Verde	75	20	15	40	12	83
Chile	63	49	28	86	12	68
China (People's Republic of China)	80	43	66	30	77	24
Colombia	67	29	64	80	6	83
Costa Rica	35	15	21	86		
Croatia	73	42	40	80	40	33
Czech Republic	57	70	57	74	51	29
Denmark	18	89	16	23	59	70
Dominican Republic	65	38	65	45	11	54
Ecuador	78	24	63	67	24	
Egypt	80	13	55	55	22	0
El Salvador	66	19	40	94	20	89
Estonia	40	62	30	60	71	16
Ethiopia	70	7	65	55	14	46
Fiji	78	14	46	48		
Finland	33	75	26	59	63	57

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A. Cultural Dimension Values by Hofstede

Country	PD	IDV	MAS	UA	LTO	IND
France	68	74	43	86	60	48
Georgia	65	15	55	85	24	32
Germany	35	79	66	65	57	40
Ghana	80	9	40	65	1	72
Greece	60	59	57	100	51	50
Guatemala	95	36	37	98	25	
Honduras	80	20	40	50		
Hong Kong	68	50	57	29	93	17
Hungary	46	71	88	82	45	31
Iceland	30	83	10	50	57	67
India	77	24	56	40	51	26
Indonesia	78	5	46	48	29	38
Iran	58	23	43	59	30	40
Iraq	97	25	53	96	11	23
Ireland	28	58	68	35	51	65
Israel	13	56	47	81	47	
Italy	50	53	70	75	39	30
Jamaica	45	39	68	13		
Japan	54	62	95	92	100	42
Jordan	70	20	45	65	20	43
Kazakhstan	88	20	50	88	85	22
Kenya	70	4	60	50	11	
South Korea	60	58	39	85	86	29
Kuwait	90	28	40	80	31	
Latvia	44	70	9	63	69	13
Lebanon	62	27	48	57	47	10
Libya	100	17	66	67	22	74
Lithuania	42	55	19	65	49	16
Luxembourg	40	60	50	70	64	56
Malawi	70	30	40	50		
Malaysia	100	27	50	36	47	57
Malta	56	59	47	96	47	66
Mexico	81	34	69	82	23	97
Moldova	90	27	39	95	71	19
Mongolia	93	37	29	39	50	42
Montenegro	88	27	48	90	40	20
Morocco	70	24	53	68	25	25
Mozambique	85	15	38	44	11	80
Namibia	65	30	40	45	35	
Nepal	65	30	40	40		
Netherlands	38	100	14	53	67	68
New Zealand	22	69	58	49	55	75
Nigeria	80	0	60	55	8	84
North Macedonia	90	40	45	87	35	35
Norway	31	81	8	50	55	55

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Country	PD	IDV	MAS	UA	LTO	IND
Pakistan	55	5	50	70	19	0
Panama	95	11	44	86		
Paraguay	70	12	40	85	20	56
Peru	64	20	42	87	5	46
Philippines	94	17	64	44	46	42
Poland	68	47	64	93	49	29
Portugal	63	59	31	99	42	33
Puerto Rico	68	43	56	38	27	90
Qatar	93	18	55	80	14	
Romania	90	46	42	90	32	20
Russia	93	46	36	95	58	20
São tomé and príncipe	75	37	24	70	32	41
Saudi Arabia	72	48	43	64	27	14
Senegal	70	25	45	55	25	
Serbia	86	42	43	92	37	28
Sierra Leone	70	20	40	50		
Singapore	74	43	48	8	67	46
Slovakia	100	57	100	51	53	28
Slovenia	71	81	19	88	50	48
South Africa	49	23	63	49	18	63
Spain	57	67	42	86	47	44
Sri Lanka	80	35	10	45	45	
Suriname	85	47	37	92		
Sweden	31	87	5	29	52	78
Switzerland	34	79	70	58	42	66
Syria	80	35	52	60	30	
Taiwan	58	40	45	69	87	49
Tanzania	70	25	40	50	34	38
Thailand	64	19	34	64	67	45
Trinidad and Tobago	47	25	58	55	17	80
Tunisia	70	27	40	75	24	
Turkey	66	46	45	85	35	49
Ukraine	92	55	27	95	51	14
United Arab Emirates	74	36	52	66	22	22
United Kingdom	35	76	66	35	60	69
United States	40	60	62	46	50	68
Uruguay	61	60	38	98	28	53
Venezuela	81	26	73	76	0	100
Vietnam	70	30	40	30	47	35
Zambia	60	35	40	50	30	42
<i>Botswana¹</i>	<i>64</i>	<i>27</i>	<i>41</i>	<i>51</i>	<i>23</i>	<i>63</i>

¹calculated with the average of the surrounding countries' values (Namibia, Angola, Zambia, South Africa)

B. Results of Literature Analysis

Table B.1.: Literature analysis of example applications for large interactive displays. Abbreviations: NAV = navigation, FUNC = functionalities, LOD = level of detail, STR = structure, DEN = density, TYP = content type, FB = feedback, SUP = support, COL = colorfulness, SAT = saturation, PTR = picture-text-ratio, MM = multimodality, INF = informativeness, GEN = gender, JOY = joyfulness.

Reference	Application Name	Culturally Relevant UI Aspects														
		NAV	FUNC	LOD	STR	DEN	TYP	FB	SUP	COL	SAT	PTR	MM	INF	GEN	JOY
Kim et al. [104]	Thunderpunch		x	x	x	x	x			x	x	x	x	x		x
Su et al. [227]	SAGE2	x	x	x	x	x	x			x	x	x		x		
Bove [21]	Time Machine	x	x	x	x	x	x			x	x	x		x		x
Çetin et al. [28]	V4-SPACE	x	x	x	x	x	x			x	x	x		x		
Yu and Fei [247]			x	x		x	x					x				x
Langner et al. [123]		x	x	x	x	x	x			x	x			x		
Knudsen and Hornbaek [107]	PADE	x	x	x	x	x	x		x	x				x		
Agarwal et al. [3]	VisWall	x	x	x	x	x	x		x	x		x		x		
Alhakamy et al. [6]	DiscoveryPlace	x	x	x		x	x		x	x				x		x
Naber et al. [161]	smart city displays	x	x	x	x	x	x			x	x	x		x		x
Parthiban et al. [176]	LUI	x	x	x	x	x	x		x	x	x	x		x		x
Burks et al. [24]	VisSnippets (SAGE2)	x	x	x	x	x	x			x	x	x		x		
Mayer et al. [149]	Pac-Many	x	x	x		x	x	x		x	x	x		x		x
Ghare et al. [64]	PLID		x	x	x	x	x		x	x		x		x		x
Wehbe et al. [243]	PLID	x	x	x		x	x			x	x			x		x
Dickson et al. [45]	CurorTap		x	x		x	x			x	x			x		x
Matsuda and Komuro [147]		x	x	x	x	x	x			x	x	x		x		x
Tokunaga et al. [232]	CollaboPlaner	x	x	x	x	x	x			x	x	x		x		x
Lee et al. [125]	DNP	x	x	x	x	x	x			x	x			x		
Michielsen et al. [155]	Story Maker	x	x	x	x	x	x		x	x	x	x		x		x

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B. Results of Literature Analysis

Reference	Application Name		Culturally Relevant UI Aspects													
			NAV	FUNC	LOD	STR	DEN	TYP	FB	SUP	COL	SAT	PTR	MM	INF	GEN
Sigitov et al. [212]	Connect-the-Dots		x	x		x				x				x		x
Rubegni et al. [198]	Interactive Art Jigsaw		x	x	x	x	x			x	x	x		x		x
Pafla et al. [173]	PLID, Band-wagon		x	x	x	x	x		x	x	x	x		x		x
Gentile et al. [60]			x	x	x	x	x	x					x			x
Kovacevic et al. [119]	Retzzles		x	x	x	x	x	x		x	x	x	x		x	x
Coenen and Vande Movere [34]	Running statistics		x	x	x	x	x	x			x	x	x		x	x
Maquil et al. [134]			x	x	x	x	x	x			x	x	x		x	x
Clayphan et al. [32]	MuseWork		x	x	x	x	x	x		x	x	x	x	x	x	x
Horak et al. [92]	David vs. Goliath		x	x	x	x	x	x			x	x	x	x	x	
Fietkau and Stojko [54]	CommunityMirror		x	x	x	x	x	x		x	x	x	x		x	x
Patterson and Clinch [177]	SlideTalk		x	x	x	x	x	x		x						
Okuya et al. [171]	ShapeCompare		x	x	x	x	x	x			x		x		x	
Kobayashi et al. [109]	SageRDI		x	x	x	x	x	x			x		x		x	
Gong et al. [66]	Side-by-side vs. Face-to-face		x	x	x	x	x	x			x	x			x	
Wang and Chen [241]			x	x	x	x	x	x			x	x	x		x	x
Gentile et al. [61]			x	x	x	x	x	x			x	x	x		x	x
Kühn et al. [120]	Public transport		x	x	x	x	x	x		x	x	x	x		x	x
Behrens et al. [16]	The Entertainer		x	x	x	x	x	x			x	x	x		x	x
Craig and Liu [38]	HotelFinder		x	x	x	x	x	x			x	x	x		x	x
Ruttkay [200]	ColourMirror			x	x	x	x	x			x	x	x		x	x
Sluÿters et al. [213]	LUI		x	x	x	x	x	x		x	x	x	x		x	x
Remizova et al. [190]	PigScape		x	x	x	x	x			x	x	x	x		x	x
Namnakani et al. [165]	GazeCast		x	x	x	x	x	x		x	x	x	x		x	x
Courtoux et al. [37]	SurfAirs		x	x	x	x	x	x			x	x	x		x	
Lou et al. [130]			x	x	x	x	x	x			x	x			x	
Mäkelä et al. [133]	CommunityMirror		x	x	x	x	x	x		x	x	x	x		x	x
Sugiura et al. [229]			x	x	x	x	x	x			x	x	x		x	x
Sharma and Radke [211]	CRAIVE		x	x	x	x	x	x		x	x	x	x	x	x	x

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Reference	Application Name	Culturally Relevant UI Aspects														
		NAV	FUNC	LOD	STR	DEN	TYP	FB	SUP	COL	SAT	PTR	MM	INF	GEN	JOY
Reibert et al. [185]		x	x	x	x	x	x			x	x			x		
Kirshenbaum et al. [106]	SAGE2	x	x	x	x	x	x			x	x	x		x		
Sakakibara et al. [201]	whack-amole	x	x	x	x	x	x			x	x	x		x		x
Montoya Freire et al. [156]	display foraging	x	x	x	x	x	x			x	x	x		x		
Craig and Liu [39]		x	x	x	x	x	x		x	x	x			x		
Keller et al. [102]	SmartWindow	x	x	x	x	x	x		x	x	x	x		x		
Erazo et al. [48]		x	x	x	x	x	x			x	x			x		x
Matulic and Vogel [148]		x	x	x	x	x	x	x	x	x	x	x		x		x
Mäkelä et al. [132]	SimSense – Pocket Transfer	x	x	x	x	x	x		x	x	x	x		x		
Parker et al. [175]	Selfie box	x	x	x	x	x	x		x			x		x		x
Mäkelä et al. [131]	Information wall	x	x	x	x	x	x		x	x	x	x		x		
Aurisano et al. [11]	Ditto	x	x	x	x	x	x			x	x	x		x		
Nakai et al. [164]	HyperReM	x	x	x	x	x	x			x	x	x		x		
Kobayashi et al. [108]	LandSAGE	x	x	x	x	x	x			x	x	x		x		
Guillermo et al. [69]	LandSAGE	x	x	x	x	x	x			x	x	x		x		
Kukka et al. [121]	UbiLibrary	x	x	x	x	x	x			x	x	x		x	x	
Leonidis et al. [127]	CognitOS	x	x	x		x	x			x	x					
Pietriga [182]		x	x	x	x	x	x			x	x	x		x		
Kawanabe et al. [101]	ChOWDER	x	x	x	x	x	x			x	x	x		x		
Kim et al. [105]		x	x	x	x	x	x		x	x	x	x		x		

C. Data of UEQ-S

Table C.1.: Overview of the overall UEQ-S ratings for each participant, each item (1–8), and each version.

Baseline									Version 1								Version 2							
ID	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
158	6	7	6	4	6	6	4	5	6	7	3	3	7	7	4	4	7	7	7	4	6	6	4	5
159	6	6	3	5	4	5	7	6	6	6	5	5	5	4	6	6	6	6	6	6	4	4	6	6
173	5	3	3	2	5	5	5	5	5	5	3	2	5	5	5	5	5	3	3	3	5	5	5	5
171	5	3	2	2	4	5	4	5	2	2	2	2	4	5	3	3	6	2	2	6	4	4	4	4
177	7	7	7	7	6	7	7	7	6	7	7	5	6	6	7	7	7	7	7	7	6	7	7	7
181	5	6	6	5	6	6	6	6	5	6	6	5	6	4	4	6	6	6	6	6	5	6	5	5
183	3	5	3	3	3	2	4	4	3	4	4	3	3	3	4	4	3	2	3	3	4	3	4	4
188	3	5	3	3	4	5	7	5	5	5	4	5	5	5	5	5	5	6	5	4	5	5	5	5
190	7	6	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
211	2	4	3	4	6	6	7	7	3	3	3	3	6	6	6	6	7	2	2	3	4	3	6	6
217	6	7	2	3	5	6	3	3	6	5	3	5	5	5	3	3	6	5	4	5	5	6	4	4
218	5	4	3	4	5	5	5	4	5	5	5	5	5	5	5	5	6	5	5	6	5	5	6	6
219	5	7	4	5	6	6	1	4	5	7	5	3	6	5	1	3	7	7	5	6	6	6	5	4
232	6	6	6	5	4	5	5	3	6	4	5	5	6	6	4	4	7	6	6	6	4	5	4	4
235	3	6	6	4	7	6	4	5	3	5	4	3	4	5	2	4	6	6	5	5	5	4	5	5
244	6	6	5	5	7	7	6	5	6	6	5	6	7	7	6	6	6	6	5	6	5	5	5	5
248	6	6	5	5	5	6	5	5	4	5	3	4	4	5	5	5	7	6	6	6	6	6	6	6
250	5	6	4	7	5	5	6	6	5	6	5	7	6	6	6	6	4	5	4	3	4	5	5	5
207	2	3	1	2	4	4	6	6	2	3	2	2	4	4	6	6	3	2	2	2	4	4	5	6
254	4	3	5	5	5	4	5	5	4	5	4	6	4	5	5	5	5	3	4	4	3	5	4	5
268	4	3	3	2	3	4	3	3	4	4	4	4	4	5	3	3	5	5	5	5	5	5	4	4
288	6	5	7	6	7	7	6	4	7	7	7	7	6	6	6	4	6	7	7	5	7	7	6	4
299	2	3	2	2	1	1	3	2	3	4	4	3	2	2	3	3	5	5	5	4	4	5	4	4
298	2	3	2	3	1	5	4	2	5	5	5	6	3	5	4	3	6	6	5	6	4	5	4	4

D. Summary of Original Phrases From Semi-Structured Interviews

Table D.1.: Original phrases from semi-structured interviews if they were not in English and were translated.

Nr	Group	ID	Original Phrase
1	1	159	Man sieht hier bei der Version 1 halt auch, dass das komplett, dass das einfach too much ist. [...] Es wirkt wie Durcheinander, es ist einfach too much.
2	1	173	Also das war halt einfach dann zu viel.
3	1	177	Ja, zwei ist mir gleich zu viel gewesen.
4	1	181	wenn zu viele Inhalte, dann zu viel Text, dass man, und dann, wenn dann auch noch zu viele Elemente vorhanden sind, dass man sich dann schwer tut, sich zu konzentrieren.
5	1	181	[...] für mich war diese Version übersichtlicher.
6	1	159	Aber jetzt, wenn man es so anschaut, kann es fast ein bisschen mehr sein (als Baseline).
7	1	158	ich finde es, wahrscheinlich ist doch, äh, besser von der Informationsflow her, dass das ein bisschen mehr (von) diese Bubbles (herum)fliegen.
8	1	173	weil einfach man dann doch die Zeit hatte, sich was auszuwählen. [...] Wenn man dann [...] gesagt hat, okay, mich interessiert nix, kann man ja immer noch den Refresh-Button drücken.
9	1	171	Vom Bauch her am meisten tatsächlich, glaube ich, das Blaue.
10	1	159	Wer viel mag und der vielleicht eine halbe Stunde vor dem Ding steht, der braucht dann wahrscheinlich die Variante
11	1	158	[...] dann hab ich das Gefühl, [...] dass (wenn) ich als User vorm Bildschirm stehe, äh, sollte doch schnell wie möglich durch die Bubbles die Information zeigen. Und ich kann doch schnell klicken für die Information, die ich suche.
12	1	159	Also, hier hat es langsamer gewirkt. Hier war halt einfach so viel Dynamik drin, dass es einfach schneller wirkt. Wenn man die beiden vergleicht.
13	1	181	Obwohl, vielleicht da waren weniger Elemente [...] aber die Bewegung war anders, also die Geschwindigkeit.

Continued on next page

D. Summary of Original Phrases From Semi-Structured Interviews

Nr	Group	ID	Original Phrase
14	1	158	Social Event als Information hat mir sehr gut gefallen. Da würde ich für die zwei Versionen tippen.
15	1	181	Also für mich, weil ich nicht fachlich unterwegs bin, diese Version (1/2).
16	1	171	Also natürlich aus der Gruppe, also aus der linken Seite.
17	1	159	[...] das war ein bisschen jünger, peppiger vom Content her.
18	1	177	Das finde ich halt einfach mal schön, weil das ist dann nicht nur Arbeit, sondern auch was betrifft die Arbeit außenrum. Und dann hast du das dann halt auch noch ein bisschen im Blickfeld, wie jetzt nur so steif.
19	1	159	Das war ein bisschen trockener.
20	1	181	Also für mich war diese Variante [Baseline] schöner zu sehen, auch weil ich das Gefühl hatte, es ist moderner, futuristischer und nicht so traditionell.
21	1	177	Aber ich bin halt eher ein bisschen ruhiger. Also ein bisschen einfach dieses Blau und dann [...] Gelbgrün. Das passt einfach sehr gut zusammen, fand ich. [...] Ich weiß auch nicht warum, aber ja. Vielleicht bist du es auch gewohnt. [...] Das beruhigt eher meine Augen, wie das Orange dann dementsprechend.
22	1	159	Also es ist so Blau und Blau, relativ langweilig, sieht aus wie so ein Windows 8 Hintergrund.
23	1	173	es ist nicht meine Farbe
24	1	171	Klar, ich finde halt Grau eine absolut grässliche Farbe, aber das ist ja auch einfach persönliche [...] Empfindung.
25	1	159	Vom Design her ist das schon ein Sprung von der Baseline zu Version 2. [...] Da ist hier ein bisschen mehr Liebe drin. Ist ein bisschen Grau im Grau, da könnte man vielleicht noch ein bisschen bei den Nuancen arbeiten. [...] Ja, Orange ist einfach ein bisschen, macht mehr Spaß, Orange anzuschauen, als Blau auf Blau.
26	1	171	Also jetzt aus marketingtechnischer Sicht würde ich natürlich sagen, dass das Orangene bessere ist, weil man halt auf den Personen hängen bleibt.'
27	1	177	gewohnensbedürftiger halt, weil es halt überhaupt nicht... Und mit dem Grau, aber sehr schön trotzdem. Also würde mir auch gefallen.
28	1	181	...ein bisschen diese Langeweile von dieser jetzt Hintergrund mit Universität der Bundeswehr und so. Es war für mich ein bisschen zu traditionell, zu Institution quasi.
29	1	173	Ja, unser orange schreit einen halt schon so ein bisschen an.

Continued on next page

Nr	Group	ID	Original Phrase
30	1	173	Also von der Bedeutung ist halt einfach hier die Unterscheidung einfacher gefallen zwischen Institut, Personen und News. Was einfach ja da dann doch ein bisschen deutlicher war als quasi das hellblaue und das dunkelblaue.
31	1	181	Ich glaube diese, da war intuitiver. Okay. Da war es für mich einfacher, die Inhalte zu unterscheiden.
32	1	159	Das ist ja zum Beispiel auch das Universitäts (logo), das sieht man ja kaum noch, weil das auch so Grau und Grau ist.
33	1	158	Da sieht man, dass man unterschiedliche Zeichen unterschiedlicher Funktionen. Das ist sehr deutlich und ist auch einfacher. Und das hat mich am meisten angesprochen, diese Änderung.
34	1	171	Also wenn ich es jetzt so spontan sagen müsste, ja klar, also die Buttons hier unten.
35	1	171	[...] weil da die Professuren mit den Personen verbunden waren.
36	1	158	Aber dann habe ich an diesen Keys gesehen, das ist überhaupt nicht deutlich. Das ist total gleiche Farbe und unterschiedliche Funktionen.
37	1	159	[...] das ist hier ein bisschen eindeutiger abgehoben.
38	1	181	Auf der anderen Seite habe ich da, wie gesagt, dieses Gefühl von Zugehörigkeit und Wärme ein bisschen mehr so quasi mitbekommen.
39	1	158	[...] die Verbindung zu der Organisation, auf jeden Fall. Ja, das finde ich gut.
40	1	171	Dann natürlich das Orangene, weil das diese Corporate Identity hat, die Farben hat.
41	1	158	Aber man sollte auch nicht als User vom Bildschirm so irgendwie überfordert fühlen, oder?
42	1	159	Ich sag mal so, das ist jetzt nichts, wo es keine technische Lösung dafür geben könnte, programmatisch, mit irgendeinem Schalter oder so, dass man einfach so Schieberegler, ich will viel Content, ich will wenig Content oder so.
43	2	183	Also, je weniger Buttons, umso besser.
44	2	188	Aber hier ist dieser Mikroskop. Wofür war es dann? [...] Ich fand die weniger Buttons besser. [...] Kann ich nicht unbedingt nötig nennen.
45	2	217	den Button [microscope] habe ich nicht verstanden. [...] Also, der Button [refresh] bringt mir halt nichts.
46	2	190	Ne, to (B) mi je previše bilo.
47	2	211	Also ich hab jetzt des (V1/2) besser gefunden.
48	2	183	Also, abgesehen davon, dass ich das, wie wir gesagt haben, mit den Personen eh nicht gut finde, aber, ähm, fand ich das, die wenigere besser.

Continued on next page

Nr	Group	ID	Original Phrase
49	2	188	Da ich das nicht gemerkt habe, würde ich sagen, dass es relativ egal ist, ob ein Name draufsteht oder nicht. [...] Hier habe ich wieder den Namen vergessen. Siehst du? Dann braucht man den Namen nicht.
50	2	217	[...] wenn man jetzt so die Personen kennenlernen, also dann mal einen Namen gehört hat und dann hat man mal ein Gesicht dazu, finde ich schon hilfreich.
51	2	190	Tu (B) možda je previše teksta bilo. Mislim previše info.
52	2	217	Äh, ja, fand ich auf jeden Fall gut.
53	2	188	Ich hatte das Gefühl, bei die beiden Versionen, dass hier (V1/2) die Kreise ein bisschen größer sind. [...] Das fand ich besser als die kleinen, weil bei kleinen kann man das nicht so gut lesen, was drin steht.
54	2	217	Hier (B) waren mehr Inhalte da und ich habe länger gebraucht, um die Inhalte registrieren zu können. [...] Dadurch, dass ich hier (V1/2) weniger auf den Kacheln zu tun hatte, würde ich gleich mit drauf schauen, konnten auch mehr da sein.
55	2	188	Also, ich würde sagen, dass die grüne, also mit den Informationen ist besser, wenn es ein bisschen mehr ist, weil die Personen meistens nicht so viel bringen.
56	2	183	Also weißt du, mich interessieren jetzt da die Leute halt so null. [...] Also mich jetzt, gell? Also abgesehen davon, dass ich die meisten ja eh nicht kenne.
57	2	188	Aber ich finde das Orange sehr gut zum Bundeswehr passt.
58	2	190	Ovo (V2) mi je super i zato jer su boje od faksa. To bi ostavila.
59	2	211	Also Farbwahl war das (V2) bei mir klar der Favorit.
60	2	217	grau-orange (V2) ist halt das, das zum Uni-Logo passt.
61	2	190	To (B) je malo previše boje.
62	2	183	Also das von der Grau-Ding, das fand ich alles ein bisschen... Also das finde ich jetzt nicht schön, sagen wir mal so.
63	2	188	Von den Ästhetischen... //S01: Fandest du das (B/V1) schöner?// Ja, genau.
64	2	217	Dieses Blauschema ist halt, es sieht schön aus, und Ding... aber sieht man auch 10.000 Mal.
65	2	188	Also hier ist es besser, weil man auch so die Knöpfe unterscheiden kann.
66	2	217	Hier habt ihr schon bei der Bedienung quasi das Ding, dass die Buttons auch zu den Kacheln die Farben haben sollten, damit das einfacher zuzuordnen ist.
67	2	217	Da habe ich halt dann die News, die dazukommen, um damit zu interagieren. Aber die sind nicht unbedingt im Vordergrund.

Continued on next page

Nr	Group	ID	Original Phrase
68	2	217	Und je nachdem, wenn es jetzt das Ziel ist, Personen vorzustellen, ist auch quasi dieser orange Akzent, das ist eine Akzentfarbe auch für die Personen da ist.
69	3	219	[...] das (V2) ist auf jeden Fall angenehmer, viel besser. Es ist viel aufgeräumter und... [...] Verwirrt mich nicht.
70	3	232	[...] ich finde das (buttons) war halt einfach übersichtlicher und eindeutiger von den Zuordnungen.
71	3	244	Und hier sehe ich halt in der letzten Version (V2) ist halt noch eine weitere Verschlinkung eingetreten, dass manche Bedienelemente, die ich persönlich für nicht wichtig halte, einfach auch einfach entfallen sind und mich nicht zusätzlich ablenken.
72	3	219	Das aktualisiert das Bild. Das kann man sowieso weglassen. Das ist nicht notwendig. [...] Genau, dieser Mikroskop war dafür da, dass man die durchklicken konnte, die Inhalte, die vom Teaser. [...] Okay, okay, ja gut, das ist Quatsch.
73	3	232	[...] den Refresh-Button, den braucht man jetzt auch nicht unbedingt. [...] Kommen ja sowieso immer neue.
74	3	219	[...] weglassen der Informationen bei den einzelnen Bubbles, das ist ganz gut gewesen. Tatsächlich, ja. Das habe ich jetzt so nicht bedacht, aber als ich es gesehen habe, habe ich gemerkt, es ist für mich angenehmer.
75	3	244	[...] sobald ich auf den Personenbutton geklickt habe, habe ich ja mein Directory an Namen und das war alphabetisch sortiert. Das tut es für mich, wenn ich von dort aus dann quasi in die Personen springen kann.
76	3	244	Weil der Lehrstuhl sagt mir dann vielleicht auch irgendwas, wenn ich da stehe, oh ja, muss ich mich mal mit dem Kollegen von [...] Professur für Usable Security and Privacy, würde mich vielleicht eher dazu bringen, auf einen Lehrstuhl drauf zu klicken.
77	3	250	Das nimmt den größten Nutzen an den Leuten. [...] Bei den Personen könnte man noch mitleben. Bei den Projekten, bei den Instituten und Professuren muss es eigentlich dran stehen. [...] bei den Instituten müsste man sonst halt auswendig wissen, welches Institut welches Bild hat.
78	3	250	Ah, das mit dem, mit dem Aufklappen finde ich sehr gut. [...] Und so entscheidet man wenigstens, okay, ich will jetzt hier mehr dazu lesen.
79	3	232	[...] wenn du draufklickst, willst du dich ja informieren, das heißt, wenn er dann weg ist, stört es mich eher, weil dann ist diese Informationskomponente nicht sofort da [...]
80	3	244	Also hier dieses zusätzliche Aufklicken nach unten würde ich darauf verzichten, wenn ich, also scrollen mit dem Finger tut es für mich.

Continued on next page

Nr	Group	ID	Original Phrase
81	3	244	Also ich komme mit dieser Version (V1), mit dieser Menge an Informationen komme ich problemlos zurecht [...]
82	3	232	Aber präferenzmäßig würde ich sagen, so ein bisschen langsamer und überschaubarer.
83	3	232	Aber ich, wie gesagt, finde die Geschwindigkeit jetzt auch nicht störend oder zu schnell.
84	3	219	Aber es ist auf jeden Fall für mich natürlich interessant, irgendwelche interessanten Informationen zu sehen, News, Publikationen, irgendwelche dtec oder Jahresveranstaltungen, was sind die Erkenntnisse.
85	3	244	[...] und da tatsächlich Artikel drin waren, die mich angesprochen haben, wohingegen ich mit den Personen halt weniger zu tun habe an dieser Stelle.
86	3	232	Ich finde es ausgeglichen besser, also Personen und Inhalte, einfach weil es auch abwechslungsreicher ist.
87	3	219	[...] wenn das jetzt der Mirror gerade für Leute sind, die außerhalb von hier herkommen, irgendwelche, keine Ahnung, Mitarbeiter von anderen Universitäten, da muss halt eine Mischung dahinter sein.
88	3	232	[...] es ist einfach für mich ansprechender und übersichtlicher [...] spricht mich am meisten an (V2). Finde ich es auch mehr ein Hingucker
89	3	219	[...] repräsentiert auch irgendwie die Farben der Universität, das ist ganz gut.
90	3	244	Wenn ich jetzt allerdings eine Firma oder eine Universität wäre, fände ich es persönlich natürlich toller, wenn irgendwie meine Unternehmensfarbpalette dort drin ist und das mag halt mal glücklicher, das mag mal unglücklicher ausgehen.
91	3	219	Also ich konnte zum Beispiel besser einordnen, dass Orange gleich zu Professor [ANONYM], sich zu Personen bezieht und halt Grau und Weiß die Informationen beinhaltet. [...] Das habe ich dann schneller wahrgenommen.
92	3	244	Wobei hier (V2) muss man natürlich sagen, [...] es bewirkt einen gewissen Fokus, aber wenn du sagst, dass es die gleiche Menge an Informationen in beiden (V1/2) drin gewesen, hat es mein Hirn hier (V2) einfacher geschafft rauszufiltern.
93	3	232	Wohingegen Personen, wenn ich Text suche, ignoriere ich die Person und kann das mehr filtern. [...] Eindeutig das (V2). War einfach viel leichter aufzuschlüsseln und zuzuordnen.
94	3	244	[...] aber hier (V1/2) siehst du den klaren Zusammenhang

Continued on next page

Nr	Group	ID	Original Phrase
95	3	250	[...] wie sie, also kodiert waren von der Farbe her, sag ich jetzt mal, war auf jeden Fall Version 1. [...] weil mir erst hier klar geworden ist, wofür die Buttons da waren.
96	3	244	Das ist aber auch eine persönliche Sache, weil du mit Blau und Grün meine zwei Lieblingsfarben erwischst hast.
97	3	244	[...] eher erwachsen wirkende, langweiliger wirkende Farbschema [...].
98	3	250	hauptsächlich einfach, weil ich den am wenigsten ansprechend fand.
99	4	268	Die Möglichkeit, Leute besser zu suchen oder auch Informationen besser zu suchen.
100	4	254	Aber es kann auch die UX verbessern, wenn... [...] also das war schon schwer zu scrollen und es war sehr klein.
101	4	298	Lieber als alle die Texte auf einmal zu bekommen.
102	4	288	Günstiger finde ich aber trotzdem, wenn ich gleich alles sehe und nicht aufklappen muss.
103	4	298	Damit ich die Verbindung zwischen Text [...] mit dieser Person machen (kann), dann brauchst du einen Namen. [...] die Funktionalität verbessert sich, wenn die Namen stehen.
104	4	268	Also optisch eher das ohne Namen.
105	4	298	Ich finde das nicht attraktiver. Also es ist eine Störung am Anfang, das zu sehen
106	4	268	Ja, von den Personen, insbesondere von den Personen. Weil das ist so ein bisschen Sinn befreit, finde ich.
107	4	298	Am Ende habe ich das bemerkt, dass es gab irgendwie... da sind plötzlich so viele Sachen auf einmal bekommen. Und richtig, tick-tick-tick, eine nach dem anderen so schnell bewegt [...].
108	4	254	[...] und dass sich die Bubbles schneller bewegen. Vielleicht bilde ich mir das nur ein, aber ich hatte den Eindruck, dass sich alles schneller bewegt und ich weniger Zeit habe und alles ein bisschen hektischer ist.
109	4	288	[...] das ist schon ein arges Gewusel. Und das war mir schon, dann, weil man ist dann doch so, ah das ist interessant und das, boah, jetzt ist es wieder weg, oh, wo ist es hin?
110	4	298	Mit der Zeit, man gewöhnt sich ein bisschen daran. Also vielleicht es war okay.
111	4	288	Aber grundsätzlich finde ich es jetzt da auch nicht so dramatisch, weil ich ja auch eine Übersicht haben kann. Wenn es mir mal richtig zu viel wird, dann sage ich, okay, dann nehme ich jetzt halt mal nur die Themen und dann schaue ich mir an, was ist denn da alles. Die Möglichkeit habe ich da ja dann. Dann ist es wieder ein bisschen entspannter.

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D. Summary of Original Phrases From Semi-Structured Interviews

Nr	Group	ID	Original Phrase
112	4	268	Also immer die News. Also News an Inhalt, News an Personen und grundsätzlich natürlich mehr Inhalt versus Personen
113	4	298	Ja, die sind zu viele Farben, zu viele Shades of Blue.
114	4		[...] ich betrachte grau so wie eine Neutralfarbe.
115	4	268	Also es war einfach, diese gleichen Farben (B/V1) finde ich ganz schrecklich. [...] Weil man versucht eine Logik zu finden. Dann diese Verwirrung mit diesem unterschiedlichen Blau, Blau-Grünlich zusammen.
116	4	254	[...] es gefällt mir, dass es mit, also dass es diesen Schema von der Uni hat.
117	4	268	Ein stringenteres Farbcoding.
118	4	254	Ich mag dieses Grüne mit dem blauen Hintergrund. Gefällt mir, sieht sehr modern aus.
119	4	288	[...] für mich ist das auch, [...] irgendwie so sachlicher, so ein bisschen wissenschaftlicher, irgendwie das Blaue, das beruhigt mich auch so ein bisschen und das wirkt auf mich jetzt seriöser
120	4	254	Da finde ich, hier gibt es hier (V1) mehr Kontrast. Hier kann man schon aus dem Farbschema lesen, dass es drei unterschiedliche Inhaltstypen gibt.
121	4	298	Aber wenn (man) in der Universität den Fokus auf die Leute legen möchte, dann ist es lieber (V2), das ist der Fokus. Wenn die Nachrichten geht um Researchlines, irgendwas, also dann andersrum.
122	4	254	[...] zum Beispiel dieser Knopf ganz rechts, der schaut fast Orange aus. Also der zweite, der sieht fast Orange aus, weil es so viel Orange drin hat. Dann ist das verwirrend.
123	4	254	Ja, ja. Ich brauche nicht die Legende nochmal extra, nicht in Farbe, nicht farblich.
124	4	298	Die Funktionalität, die Buttons hier (V1/2), also es gab eine Verbindung von Farbe, die sind inhaltlich.
125	4	288	Dass ich jetzt hier (V1, buttons) farbliche Unterschiede habe, dass ich gleich sehen kann, was ich dann da sehe.
126	4	254	Ich finde den Background, dass der Hintergrund eben der gleichen Farbe ist, finde ich schön. Ja, das finde ich positiv.

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