Second Screen Applications

A Multi-Platform Software Development Kit and Optimization of Human-Computer Interaction in Distributed Systems

Inaugural-Dissertation zur Erlangung der Doktorwürde der Fakultät für Sprach-, Literatur- und Kulturwissenschaften der Universität Regensburg

vorgelegt von

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aus

Schwabach

2019

Abgabe: Juli 2019

Tag der Disputation: 09. Dezember 2019

Erstgutachter: Prof. Dr. phil. Christian Wolff

Zweitgutachter: Jun.-Prof. Dr. rer. nat. Florian Echtler

Dedicated to my many friends, my two brothers, my four parents,

and the one who I love.

Acknowledgements

First of all, I would like to thank my supervisor Prof. Dr. Christian Wolff, who not only gave me the opportunity for this dissertation, but also for all of my studies and experiences in academia. For that, and for all the support, inspiration, and encouragement throughout the last nine years, I want to express my deepest appreciation and gratitude – it has truly been a pleasure and privilege. Also, I want to express my gratitude to Prof. Dr. Florian Echtler and all current and former members of the Chair of Media Informatics at the University of Regensburg who accompanied me since my time as a student and have taught me so much.

I would also like to thank Matthias, Roman, Matthias, and everyone else from MEKmedia who played a central role in the creation of this work. I am grateful for your exceptional kindness and the wonderful experiences I have had thanks to you.

Furthermore, I thank all of my colleagues and fellow doctoral students, who have made the last few years a very special time for me, of which I enjoyed (almost) every moment. You have broadened my horizon with interesting discussions on *all* sorts of subjects, helped me overcome every obstacle I encountered, and made every day worthwhile. I am particularly grateful to Patricia, who started me off on this journey, Thomas, from whom I have learned a great deal – both professionally and personally, and Florin, the best office partner I could have wished for – the bar you have all set will be difficult to reach in the future.

Of course, I also want to thank all my family and friends who always have and will support me.

Last and most of all I would like to thank you Sonja, who was unconditionally supportive on all levels, not only throughout the course of this dissertation, but also in all other situations of life – there are no words I know to express this gratitude.

Abstract

This dissertation addresses various aspects of the term *second screen* and the challenges involved in the development of this type of application. The term and its characteristics have been clearly delineate by the means of a structured review of literature of 65 publications and an analysis of 19 currently available commercial applications. Furthermore, a content and technical classification were created to facilitate communication and the positing of future research activity in this area.

The development of second screen applications is currently associated with a high effort, caused by the redundant implementation of multiple software platforms on both first and second screen side. In order to counteract this double multi-platform problem, an SDK was developed that facilitates the connection and communication process between the different application parts. The functionality of this 2ndS SDK was evaluated as reliable and performant and proven in several functional prototypes, which also served the purpose to examine existing and new forms of second screen interaction.

In addition to addressing the technical challenges involved in the development of second screen applications, this work presents several results regarding the optimization of human-computer interaction in this type of application. These include a collection of 55 application components raised and validated in a mixed-method approach and insights into the attention behavior in such scenarios with corresponding recommendations derived from two eye-tracking studies. Furthermore, were concrete design guidelines from existing sources abstracted and evaluated with the help of a user study, and heuristics derived for the domain second screen and extended to a checklist for the efficient identification of problems. The results presented in this work are intended to be used in a user-centered design process and aim to ease the development of second screen applications with optimized interaction, and thereby contribute to their awareness and further distribution.

Zusammenfassung

Diese Arbeit befasst sich mit dem Begriff *Second Screen* und mit den Herausforderungen bei der Entwicklung dieser Art von Anwendungen. Dazu wurden der Begriff und seine Ausprägungen mit Hilfe einer strukturierteren Literaturanalyse von 65 Veröffentlichungen und einer Analyse von 19 aktuell verfügbaren kommerziellen Anwendungen klar definiert und abgegrenzt. Des Weiteren wurde eine inhaltliche und technische Klassifikation erstellt um die Kommunikation in diesem Themenbereich zu vereinheitlichen.

Die Entwicklung von Second-Screen-Anwendungen ist mit einem hohen Aufwand verbunden, da aktuell mehrere Software-Plattformen auf sowohl First, als auch Second Screen Seite unterstützt werden sollten. Um dieser *doppelten Multiplattformproblematik* entgegenzuwirken, wurde ein SDK entwickelt, dass den Verbindungs- und Kommunikationsprozess zwischen den unterschiedlichen Anwendungsteilen erleichtert. Die Funktionalität dieses 2ndS SDK wurde in einer Evaluation als zuverlässig und performant bewertet und in mehreren funktionalen Prototypen bewiesen, bei welchen auch bestehende und neue Second-Screen-Interaktionsformen untersucht wurden.

Neben den technischen Herausforderungen bei der Entwicklung von Second-Screen-Anwendungen untersucht diese Arbeit, wie die Interaktion bei dieser Art von Anwendungen optimiert werden kann. Dazu gehören eine Sammlung von 55 Anwendungskomponenten die in einem Mixed-Methods-Ansatz erhoben und validiert wurden und Erkenntnisse bezüglich des Aufmerksamkeitsverhalten und Empfehlungen bezüglich der gezielten Lenkung aus zwei Eye-Tracking-Studien. Des Weiteren wurden konkrete Gestaltungsrichtlinien aus bestehenden Quellen abstrahiert und mit Hilfe einer Nutzerstudie bewertet, sowie Heuristiken für die Domäne Second Screen abgeleitet und zu einer Checkliste für die effiziente Bestimmung von Usability Problemen erweitert. Die Ergebnisse aus dieser Arbeit eignen sich für eine Verwendung in einem Nutzerzentrierten Entwicklungsprozess mit dem Ziel die Entwicklung von Second-Screen-Anwendungen zu erleichtern, um deren Verbreitung voranzutreiben.

Content

Figures

Tables

Part I – Introduction and Background of Second Screen

1 Introduction

Second screening

The increasing diversity of computational devices has changed the way humans interact with them in the last decade. These technological advances allow a new form of multitasking behavior referenced as *second screening*, e.g. using more than one screened devices simultaneously. This simultaneous usage of two screened devices is in general considered a widespread activity, although many are unaware of the term describing it. Most smartphone or tablet owners use their additional devices while watching TV to look up information on the current content, to participate in a social network, or just to browse the internet (Busemann & Tippelt, 2014, p. 408).

Second screen applications

The advent of *smart* counterparts to mobile devices, e.g. smart TVs, streaming sticks, or gaming consoles, opened up new interaction possibilities in form of directly connected applications, known as *second screen applications*. These dedicated second screen applications are able to offer simple extensions to the current content on the first screen, such as remote control functions or the display of additional information, but are also able to create completely new experiences designed for two different screens at the same time. This dissertation addresses multiple aspects regarding the understanding, development, and design of second screen applications, which are outlined in the following.

1.1 Problem Statement

Inconsistent use of second screening and little awareness

Despite the relevance of second screen activity, the potential of dedicated second screen applications, and existing related literature, the use of the term is still inconsistent and the behavior still not well understood (Holz, Bentley, Church, & Patel, 2015, p. 94). Most of the participants in this activity are not aware of the terminology, the potential use cases, and benefits of second screens. Most researchers in this field rarely explain their understanding of the term and its characteristics, but use it with a vague idea and reference to the same use case. Different interpretations on individual aspects exist in parallel and are rarely discussed, which increases the inconsistent understanding of the term. The little awareness

of the benefits of second screening might also contribute to the so-far small number of available commercial second screen applications, despite the existing technical infrastructure in many homes.

High effort in the development of second screen applications

A further reason for this could be the high effort needed to create these kind of applications. One factor here are the multiple platforms to be supported on both the first and second screen side in order to provide an application suitable for a sufficient number of potential users. This causes a high development effort in the connection and communication process, which must be implemented and maintained redundantly for each additional supported platform. The parallel existence of multiple software platforms in one domain, such as *Android* and *iOS*, is anything but new in software development. The combination of a heterogeneous platform landscape on the first and second screen side in one application is characteristic for the domain second screen applications and referred to as *double multi-platform problem*. This problem drastically increases the development effort of such applications and is further aggravated by the mandatory use of different development environments, programming languages, workflows, or missing solutions for some platforms.

Little knowledge on the design of second screen interaction

Apart from the technical hurdles, there is currently a lack of knowledge about the appropriate design of second screen interaction (Geerts, Leenheer, Grooff, Negenman, & Heijstraten, 2014, p. 95). The design of applications on separate screens poses a number of challenges, particularly in the direction of attention from one screen to the other or for the perception as a uniform system. Existing design recommendations and commercial applications are often contradictory in the design of second screen interaction, which poses a challenge for developers as not all expectations can be met. A further challenge can be the multitude of available features as well as their selection and prioritization in different usage context. This dissertation addresses the problems mentioned regarding the understanding, design, and development of second screen applications, of which the goals are presented in the following.

1.2 Research Goals

The development of second screen applications faces a variety of challenges, ranging from the basic understanding of the term to a combination of aspects increasing the effort in design and development. In order to facilitate the development of second screen applications, this dissertation addresses the following research objectives:

- **Present a clear definition of the term second screen and its characteristics:**
  This delimitation should serve as a basis for the discussion to advance the term and to facilitate the classification, structure, and communication of future research projects in this area (cf. Chapter 2). Furthermore, the current state of the art should be captured and reflected upon, with the ultimate goal of advancing the general understanding and increasing awareness of such applications.
- **Ease development effort of second screen applications:**
  Create a solution that addresses the *double multi-platform problem* in the development of second screen applications caused by multiple available platforms on both application parts (cf. Chapter 3 & Chapter 4). This solution should incorporate the current state of the art and contribute back to the knowledge base to solve similar problems.
- **Exploration of second screen use cases:**
  Development and evaluation of existing and new use cases with second screen interaction. The aim is to investigate the individual forms of interaction as well as the feasibility with real technical prototypes for as realistic a representation as possible (cf. Chapter 5).
- **Support of the design of second screen applications:**
  The design of one applications separated on two screens poses serval challenges, as the selection of features to implement (cf. Chapter 6), the direction of attention between the screens (cf. Chapter 7), or the consideration of several design recommendations (cf. Chapter 8). The aim is to provide reasoned recommendations for all these aspects and for the efficient identification of usability problem in this area (cf. Chapter 9).

1.3 Publications

Some of the results of this dissertation have been published in recent years and are presented below in chronological order. The chapters from which these publications originate also refer to the individual articles:

- Lohmüller, V., Schmaderer, D. & Wolff, C., (2018). Heuristiken für Second-Screen-Anwendungen. In: Dachselt, R. & Weber, G. (Hrsg.), Mensch und Computer 2018 - Tagungsband. Bonn: Gesellschaft für Informatik e.V. https://doi.org/10.18420/muc2018-mci-0266
- Lohmüller, V., Schmaderer, D. & Wolff, C., (2019). A Heuristic Checklist for Second Screen Applications. i-com: Vol. 18, No. 1. Berlin: De Gruyter. (S. 55-66). https://doi.org/10.1515/icom-2019-0003
- Lohmüller, V. & Wolff, C., (2019). Towards a Comprehensive Definition of Second Screen. In: Alt, F., Bulling, A. & Döring, T. (Hrsg.), Mensch und Computer 2019 - Tagungsband. New York: ACM. DOI: 10.1145/3340764.3340781
- Lohmüller, V., Eiermann, P., Zeitlhöfler, P. & Wolff, C., (2019). Attention Guidance in Second Screen Applications. In: Alt, F., Bulling, A. & Döring, T. (Hrsg.), Mensch und Computer 2019 - Tagungsband. New York: ACM. DOI: 10.1145/3340764.3340788

1.4 Structure of the Dissertation

This dissertation examines various aspects of the concept *second screen* in the field of media informatics. Several sub-areas of this discipline are taken up, such as the analysis, conception, realization, and evaluation of interactive and multimedia human-computer systems and the investigation of goals, requirements, and effects for the users (Malaka, Butz, & Hußmann, 2009, p. 21). The dissertation is divided into four parts to examine theoretical, technical, and empirical aspects, followed by a conclusion. This structure and the corresponding chapters are outlined below for better overview:

Part I - Introduction

Introduction to the work, theoretical consideration and processing of the concept second screen, and description of the state of the art. This part focuses on the theoretical aspects of this dissertation.

- **Chapter 1:** Introduction and context of the dissertation.
- **Chapter 2:** Description of the background of second screen with associated definitions, classifications, and presentation of the state of the art.

Part II – Multi-Platform Second Screen SDK

Development and evaluation of the 2ndS SDK and presentation of the created prototypes in this context. This part focuses on the technical aspects of this dissertation.

- **Chapter 3:** Presentation of the related literature for the development of the 2ndS SDK, e.g. *cross-platform development* and *design science research*.
- **Chapter 4:** Development and evaluation of the 2ndS SDK to address the double multi-platform problem in the development of second screen applications, structured according to the design science research approach.
- **Chapter 5:** Description of the prototypes created within the scope of this dissertation with the resulting findings for the design of the 2ndS SDK and second screen interaction.

Part III – Optimization of Second Screen

The third part presents findings that support the development of second screen applications in a user-centered design process. This part focuses on empirical and explorative studies.

- **Chapter 6:** Collection of 55 *applications components*, e.g. beneficial features in second screen applications, with instructions on how to use them.
- **Chapter 7:** Evaluation of the *attention behavior* during second screening with recommendations on how to design the direction of attention between the screens.

- **Chapter 8:** Presentation of unified design guidelines for second screen applications with recommendations on how to design second screen interaction.
- **Chapter 9:** Introduction of heuristics and a heuristics checklist adapted to the domain second screen for the efficient identification of common problems.

Part IV – Conclusion

The last part presents summaries of the most important contributions of this work with associated discussions and a final outlook.

- **Chapter 10:** Summary and discussion of the most important contributions and outlook for future work in this context.

1.5 Background of this Dissertation

This work originated as part of the project *SmartTV - multiplatform solution for second screen with optimized control for mobile devices*, which received funding from the Bavarian Ministry of Economic Affairs and Media, Energy and Technology (Grant Nr. IUK475/002). The project was realized in cooperation with *MEKmedia*, who was involved in the development of the 2ndS SDK presented here. The duration of the project was from 09/2015 until 09/2018.

2 Background of the Concept Second Screen

Increasing multitasking activity

Multitasking in the consumption of media content is as old as the media devices themselves; the first studies on the psychology of radio and its rarely isolated use date back to 1935 (Cantril & Allport, 1935). Since then, media consumption has risen steadily among all age groups (Lowenstein-Barkai & Lev-On, 2018, p. 2), also influenced by the increasing number of devices that enable media consumption as televisions, computers, and mobile devices such as smartphones and tablets. A special form of this multitasking is considered as *second screening*, i.e. the use of a second screen, which has many different characteristics and thus interpretations, and is widespread among users, although many are not aware it (Cunningham & Weinel, 2015, p. 228). The general parallel use of two screens has gained a new perspective in recent years due to technological changes that make it possible to connect the two screens and thereby create new experiences.

Increasing relevance of second screen applications

One of the earliest work in this field is by Robertson, Wharton, Ashworth, and Franzke (1996), in which floorplans of houses can be accessed by a PDA and associated pictures are shown on a TV. The authors do not use the term s*econd screen* or similar derivation of it in their work, but refer to it as a *dual device user interface*, which also fits modern second screen applications. The bi-directional communication between the two devices was achieved with a wireless infrared technology, which is rather error prone and cumbersome compared to modern communication technologies. Most of the earlier work in the field of second screening focuses on the development of applications to explore new experiences or overcome technical challenges[1]. The technical infrastructure that enables these new applications is now available for an increasing number of users through a growing distribution of *smart* first and second screens as well as Wi-Fi, which increases the relevance of second screen applications. Well-known examples of this type of application are *Netflix*, *Amazon Prime Video* or *YouTube*, which with

[1] Bentley and Groble (2009); Cesar, Bulterman, and Jansen (2008); Cruickshank, Tsekleves, Whitham, Hill, and Kondo (2007); Geerts, Cesar, and Bulterman (2008); Obrist, Moser, Alliez, Holocher, and Tscheligi (2009); Robertson et al. (1996); Tsekleves, Whitham, Kondo, and Hill (2009)

the appropriate hardware allow content selection and playback control via a mobile connected device and already have an enormous distribution among users.

Chapter contributions

Despite the high prevalence of general second screen activity and the increasing relevance of second screen applications, there is currently no clear definition of the term in the relevant literature. In order to evaluate these different available interpretations, a structured review of literature (SRL) on 65 publications in this area was conducted and reflected on the results of an analysis of currently available second screen applications to provide more clarity on the subject with the following contributions[2]:

- A reflection of the current interpretation of *second screening* in scientific literature, commercial applications.
- A reasoned discussion and delimitation of the term *second screening* and its characteristics.
- A *content* and *technological* classification for second screen applications.

Chapter structure

Section 2.1 describes the methodology used to define *second screen*, a systematic review of literature and market analysis, Section 2.2 present the thereby obtained results with the associated definition. Section 2.3 introduces the created content and technical classification of second screen applications, and Section 2.4 gives an overview on the insights of second screen behavior obtained by the later studies in this work before a brief summary of this chapter is presented in Section 2.5.

[2] The results of Chapter 2 are published as: Lohmüller, V., & Wolff, C., (2019). Towards a Comprehensive Definition of Second Screen [to appear]. In: Mensch und Computer 2019 – Tagungsband. New York, NY, USA: ACM. https://doi.org/10.1145/3340764.3340781

2.1 Methodology to Define Second Screen

Overview methodology

A *Systematic Review of Literature* (SRL) of 65 papers was conducted to assess the current understanding of *second screening* in the scientific community and as a basis for the classification of second screen applications. In addition, 19 currently available second screen applications were evaluated to deepen the understanding on the current situation. The review of literature and the analysis of commercial applications was carried out from December 2018 to January 2019. At the time of the realization, no comparable project for the fundamental delimitation and discussion of the concept of second screen was known, apart from individual works suggesting classifications of the benefits of this type of use, which are discussed in section 2.3.1.1. Figure 2-1 shows the methodology used in the SRL and market analysis to delineate the term *second screen* and to establish a classification of second screen applications.

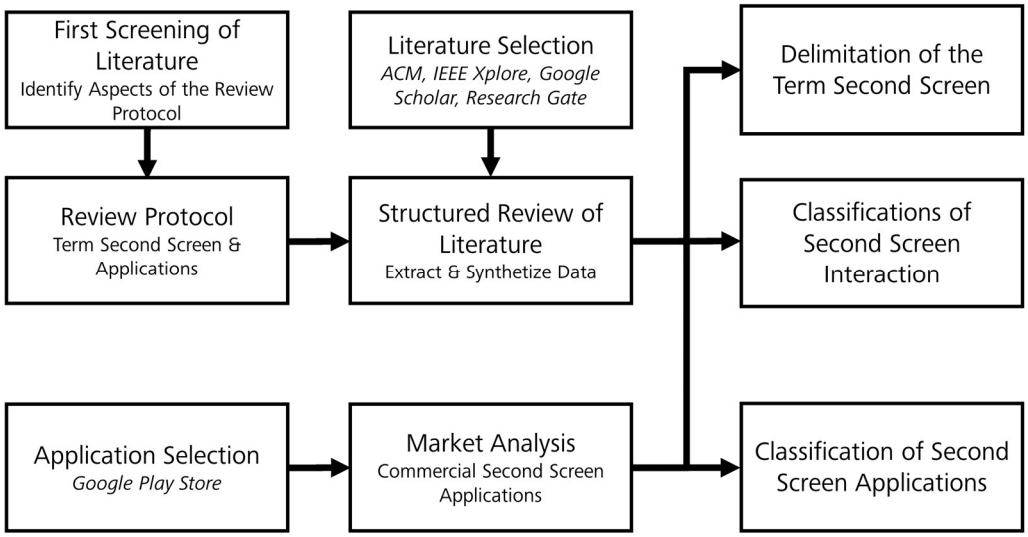

Figure 2-1: Applied methodology in the SRL and market analysis to delineate the term second screen and create a classification of second screen applications

2.1.1 Systematic Review of Literature (SRL)

SRL procedure

The following methodology has been applied according to the procedures Kitchenham´s (Brereton, Kitchenham, Budgen, Turner, & Khalil, 2007; Kitchenham, 2004) to carry out systematic reviews. The aim of this procedure is to obtain a balanced and objective assessment of concept second screening according to the current state of the art by applying the following steps:

- Identification of the need for the review.
- Development of a review protocol.
- Identification of research & selection of studies.
- Data extraction & synthesis.

Identification of the need for the review

The need for the review

The need for this SRL emerges from different interpretations and lack of common understanding of the term *second screen* in scientific literature and other sources. The different interpretations on various aspects are discussed in more detail in the next section. Due to the wide range of uses within the context of second screening and technical possibilities for its implementation, it is necessary to create a uniform overview through systematization in order to appropriately position new research activities (Kitchenham, 2004, p. 2).

Development of a review protocol

A review protocol for the SRL was developed to conduct a structured analysis and minimize potential bias (Kitchenham, 2004, p. 4). The research question to be answered by the review was the determination of the different interpretations regarding the term *second screening*, its associated characteristics, and the nature of the corresponding applications. For this purpose, a structure was created from an exploratory reading of the literature, which contains the most frequently mentioned aspects in this regard:

Developed protocol regarding the term second screen

- Relation of first screens towards *television* and *television content*.
- Requirement of an *internet connection* on the second screen.
- Mentioning of the second screen with mobile devices (smartphone or tablet).
- Interpretation of second screening as purely content-related use.

- Inclusion of *any* content as second screening.
- Mention of *simultaneous* use of both screens.
- Non-use of the term second screen, but still relevant.
- No further description for the interpretation of second screening.

After the protocol was developed, the different interpretations of the term second screen in the identified literature were registered in order to create an overview on the current situation, of which the results are presented in Section 2.2.1.

Apart from the varying interpretation of the term, the types of applications developed were included in the protocol, whereby the following aspects were derived from the exploratory reading of the literature. In addition to the description and the technical implementation of the applications, the type of benefits provided were recorded and classified into five categories: *information*, *social*, *games*, *control* and *other*. These aspects are referred to as the *ISGCO* classification and is described in more detail in Section 2.3.1. In the following, the aspects collected in the literature regarding second screen applications are presented:

Developed protocol regarding second screen applications

- Description of the application
- Application benefit
  - Information (I)
  - Social (S)
  - Games (G)
  - Control (C)
  - Other (O)
- Technical approach
- Second screen device
- First screen device & content

Identification of research & selection of studies

Literature identification

The text corpus of the literature review was retrieved from the *ACM Digital Library*, *IEEE Xplore*, the reference lists of primary studies and monographies, *Google Scholar*, but also from *ResearchGate*, and additional Internet research using *Google* as a general purpose search engine. The searches revolved around the term *second screen* in various derivations (Kitchenham, 2004, p. 8), namely *second screens*, *second screening*, *secondary screen*, and each of the previous terms spelled

with a hyphen (e.g. *second-screen*). Additionally term *companion screen* was added to the search analogous to *second screen*. To reflect the scientific state of the art, the literature found was expected to have been published as journal article, a contribution to a conference, or as monography. The literature found was screened for relevance to the research goals by being related to the broad topic of second screen activity and applications in the general context of HCI, which left 65 items to the analysis. In order to take as many publications as possible into consideration, no additional exclusion criteria were applied to remove further publications from the review.

Data extraction & synthesis

Review execution

With the help of the previous developed protocol, the data from the selected literature was extracted in a structured manner and synthesized by collating and summarizing the gathered results.

2.1.2 Market Analysis

Identification second screen applications

In order to broaden the perspective of the classifications and delimitations created here beyond the area of scientific literature, the *Google Play Store* was searched for commercial second screen applications for a market analysis. Thereby the very problem was encountered which is addressed here: the non-uniform use of the terms *second* and *companion screen*. Thereby mainly remote control applications like the *PS4 Second Screen* or *screen mirroring* applications were found, most of them with low download numbers. The most prominent applications related to second screening are media libraries applications such as *Netflix*, *Amazon Prime Video* or *YouTube*, and do not use the relevant keywords, which makes a structured search more difficult. Based on these known applications and the previous literature analysis more applications were identified, less with the aim of creating an absolute overview, but a profile of the current status. The found applications needed at least 500.000 downloads to be considered as relevant, but most of the selected applications have a far wider range of distribution, leaving 19 applications to be included in the analysis. In order to allow a structured evaluation, the protocol for the evaluation of the applications in the

SRL was used (cf. Chapter 2.1.1), which records the technical implementation and the type of benefits provided by the application, classified according to the *IS-GCO* classification (cf. Chapter 2.3.1).

2.2 Delimitation of the Term Second Screening

This section first describes the data collected from the SRL before discussing it to delineate the terms *second*, *companion* and *multi-screen* and their characteristics.

2.2.1 Results of Structured Review of Literature

Overview results SRL

The most frequently cited aspects regarding second screens are the reference to *mobile devices* (40.0%), a *television* device or content (35.4%), and the *simultaneous* use of two screened devices (21.5%). Less frequently mentioned aspects of second screens are the availability of an *Internet connection* (12.3%) and the limitation to *content-related use* (7.7%), as opposed to the inclusion of *any type of content* (12.8%). 13.8% of the reviewed work does not use the term *second screen*, or derivations of it at all but still contribute to this field according to this interpretation[3]. On the other hand, one work was also found in which a second screen application was developed for theatrical live performances without the presence of a first screen (Barkhuus, Engström, & Zoric, 2014), which is not to be classified as second screening according to the assessment of this work. However, most literature (49.2 %) has not further elaborated its interpretation of the term *second* or *companion screen* and has only used it. Table 2-1 shows the identified aspects and the related literature representing them.

[3] Dezfuli, Günther, Khalilbeigi, Mühlhäuser, and Huber (2013); Martin and Holtzman (2010); Obrist et al. (2009); Shokrpour and Darnell (2017); Sahibzada, Hornecker, Echtler, and Fischer (2017); Weißker, Berst, Hartmann, and Echtler (2016); Ohmata, Ikeo, Ogawa, Takiguchi, and Fujisawa (2018); Vinayagamoorthy, Ramdhany, and Hammond (2016)

Second Screen Aspect	References (n =65)	Percentage
First screen is a *TV device* or *TV content*	Abreu, Almeida, Silva, & Aresta, 2016; Almeida et al., 2015; Angeluci, Calixto, Bevilaqua, Bernardini, & Gobbi, 2017; Anstead, Benford, Glancy, Rasul, & Valentine-House, 2010; Anstead, Benford, & Houghton, 2014; Badii et al., 2015; Brown et al., 2014; Busemann & Tippelt, 2014; Cesar et al., 2008; Courtois & D'heer, 2012; Doughty, Rowland, & Lawson, 2012; Duong, Howson, & Legallais, 2012; Gil de Zúñiga, Garcia-Perdomo, & McGregor, 2015; Guo & Holmes, 2016; Johnen & Stark, 2015; Lowenstein-Barkai & Lev-On, 2018; Morales & Shekhawat, 2013; Nagel, 2016; Neate, Evans, & Matt, 2017; Stauff, 2015; Vanattenhoven & Geerts, 2017; Vinayagamoorthy et al., 2016; Ziegler, 2013	35.4 %
Internet connection required	Busemann & Tippelt, 2014; Cerny & Donahoo, 2016; Doughty et al., 2012; Duong et al., 2012; Gil de Zúñiga et al., 2015; Holz et al., 2015; Johnen & Stark, 2015; Lowenstein-Barkai & Lev-On, 2018	12.3 %
Limitation to content-related use	Angeluci et al., 2017; Gil de Zúñiga et al., 2015; Lowenstein-Barkai & Lev-On, 2018; Nagel, 2016; Stauff, 2015	7.7 %

Second Screen Aspect	References (n =65)	Percentage
Mobile devices (smartphone or tablet)	Abreu, Almeida, Silva et al., 2016; Abreu, Almeida, Teles, & Reis, 2013; Angeluci et al., 2017; Anstead et al., 2010; Anstead et al., 2014; Badii et al., 2015; Bernhaupt, Pirker, & Gatellier, 2013; Brown et al., 2014; Courtois & D'heer, 2012; Cunningham & Weinel, 2015; D'heer, Courtois, & Paulussen, 2012; Doughty et al., 2012; Duong et al., 2012; Geerts et al., 2014; Menychtas et al., 2015; Morales & Shekhawat, 2013; Mosqueira-Rey, Alonso-Ríos, Prado-Gesto, & Moret-Bonillo, 2017; Mu, Knowles, Sani, Mauthe, & Race, 2015; Nagel, 2016; Neate et al., 2017; Neate, Evans, & Jones, 2016; Pagno, Costa, Guedes, Freitas, & Nedel, 2015; Simon, Comunello, & Wangenheim, 2013; Stauff, 2015; Vinayagamoorthy et al., 2016; Ziegler, 2013	40.0 %
Inclusion of any kind of use	Almeida et al., 2015; Anstead et al., 2014; Brown et al., 2014; Busemann & Tippelt, 2014; Cunningham & Weinel, 2015; D'heer et al., 2012; Johnen & Stark, 2015; Menychtas et al., 2015; Mosqueira-Rey et al., 2017; Neate et al., 2016; Negenman, Heijstraten, Vanattenhoven, & Geerts, 2016; Vanattenhoven & Geerts, 2017	18.4 %
Do not use the term *second screen* but still contributes	Dezfuli et al., 2013; Martin & Holtzman, 2010; Obrist et al., 2009; Ohmata et al., 2018; Sahibzada et al., 2017; Shokrpour & Darnell, 2017; Vinayagamoorthy et al., 2016; Weißker et al., 2016	13.8 %

Second Screen Aspect	References (n =65)	Percentage
Simultaneous use	Almeida et al., 2015; Angeluci et al., 2017; Busemann & Tippelt, 2014; Cunningham & Weinel, 2015; Gil de Zúñiga et al., 2015; Johnen & Stark, 2015; Lowenstein-Barkai & Lev-On, 2018; Morales & Shekhawat, 2013; Mosqueira-Rey et al., 2017; Mukherjee & Jansen, 2015; Neate et al., 2017; Vanattenhoven & Geerts, 2017; Vinayagamoorthy et al., 2016; Ziegler, 2013	21.5 %
No further description on interpretation *second screening*	Abreu et al., 2013; Abreu, Almeida, & Silva, 2016; Abreu, Almeida, Silva et al., 2016; Basapur et al., 2011; Basapur et al., 2012; Bentley & Groble, 2009; Bernhaupt et al., 2013; Brown et al., 2014; Cerny & Donahoo, 2016; Cruickshank et al., 2007; D'heer et al., 2012; Duong et al., 2012; Geerts et al., 2008; Geerts et al., 2014; Grubert, Kranz, & Quigley, 2016; Hess, Ley, Ogonowski, Wan, & Wulf, 2011; Holmes, Josephson, & Carney, 2012; Holz et al., 2015; Huber, Buschek, & Alt, 2017; Mu et al., 2015; Murray et al., 2012; Neate et al., 2016; Neate, Jones, & Evans, 2015a, 2015b; Negenman et al., 2016; Ohmata et al., 2018; Pagno et al., 2015; Regal et al., 2013; Silva et al., 2015; Simon et al., 2013; Tsekleves et al., 2009; Ziegler, Keimel, Ramdhany, & Vinayagamoorthy, 2017	49.2 %

Table 2-1: Identified aspects to the term *second screening* in the review protocol SRL with references representing them.

2.2.1.1 *Results Distribution of Second Screen Activity*

Second screen activity is widespread

Second screening was found to be a highly distributed activity across several studies (Cunningham & Weinel, 2015; Deloitte, 2016; Holz et al., 2015, 2015; Johnen & Stark, 2015; Shokrpour & Darnell, 2017; The Nielsen Company, 2017), even if users might be unaware of it or do not know the term for this behavior (Cunningham & Weinel, 2015). These studies used various methodological approaches to determine how many people generally use an additional device as second screen, how much time is spent with them, and what content is consumed.

Found distribution in questionnaire studies

As across all fields of research, self-reporting questionnaires are one of the most commonly used methods, as they are capable of obtaining a large number of responses quickly. The data collected on the general use of second screens vary from 58% (The Nielsen Company, 2017), over 83% (Johnen & Stark, 2015), up to 92% (Deloitte, 2016) in these studies. A possible factor for these differences, in addition to the time and place of the surveys, could be the general difficulty of correctly assessing one's own behavior in a questionnaire (Lazar, Feng, & Hochheiser, 2010, p. 101).

Found distribution in other approaches

Therefore, other studies tried to capture *natural* second screen activity with real life observations. Shokrpour & Darnell (Shokrpour & Darnell, 2017) found that about 40% of the time *watching* television was spent multitasking (not looking at TV) and the time spent with a second screen was about 14,4% of the total time. A study with an app logger installed on users devices found second screen activity as high as 35% of program and 30.2% of commercial TV time (Holz et al., 2015). A study by Lowenstein-Barkai and Azi Lev-On (2018) with an similar approach only found 9% of users *not* multitasking while watching TV.

2.2.1.2 *Results Content-Related and Unrelated Use*

The inclusion of any use is more frequent in literature

The *content consumed* on the second screen represents one of the most basic and influential aspects, since unrelated content represents the major part of all second screen activity (Busemann & Tippelt, 2014; Deloitte, 2016; D'heer et al., 2012; Holz et al., 2015; Johnen & Stark, 2015; Shokrpour & Darnell, 2017). Opinions differ as to whether this non-content related activity on the second screen should be considered as a second screening or not. Five (7.7%) of the scientific papers analyzed

in the SRL argue that second screening should be considered as an exclusively content-related use and 12 (18.4%) to include any type of activity[4]. However, most sources do not go into more detail on their interpretation in this respect.

Content unrelated use is predominant

One reason for the broader interpretation of the term is the high prevalence of unrelated use of the second screen found in literature. Studies with different methodologies agree with their findings of this wide distribution in general, but the amount of content-related use varies. Self-reporting studies found 34% (Busemann & Tippelt, 2014), 24% (Deloitte, 2016), or general rarely related (Johnen & Stark, 2015) content-related use of second screens, such as finding further information on the current content or social media activity related to the program. Other studies generate results by logging mobile devices or direct observation and find *virtually none* content-related activity on the second screen (D'heer et al., 2012; Holz et al., 2015), or only 4% of the total TV time (Shokrpour & Darnell, 2017).

2.2.1.3 *First and Second Screen Devices*

Televisions are typical first screens

The type of device potentially available as first or second screen is another central aspect in the context of second screening. The most frequently cited scenario in this respect consists of a *television* set as the first and a *mobile device*, such as a smartphone or tablet, as the second screen. 35.4% of the analyzed work mentions a television set or television content as *first screen* in this context[5], whereby other devices and contents are not explicitly excluded, but are not mentioned. However, there are also examples in the literature for novel applications with other types of first screens such as for movie theaters (Cunningham & Weinel, 2015),

[4] Menychtas et al. (2015); Almeida et al. (2015); Anstead et al. (2014); Brown et al. (2014); Busemann and Tippelt (2014); Cunningham and Weinel (2015); D'heer et al. (2012); Johnen and Stark (2015); Mosqueira-Rey et al. (2017); Neate et al. (2016); Negenman et al. (2016); Vanattenhoven and Geerts (2017)

[5] Almeida et al. (2015); Angeluci et al. (2017); Anstead et al. (2010); Anstead et al. (2014); Badii et al. (2015); Brown et al. (2014); Busemann and Tippelt (2014); Cesar et al. (2008); Courtois and D'heer (2012); Doughty et al. (2012); Duong et al. (2012); Gil de Zúñiga et al. (2015); Guo and Holmes (2016); Johnen and Stark (2015); Morales and Shekhawat (2013); Nagel (2016); Stauff (2015); Vanattenhoven and Geerts (2017); Neate et al. (2017); Abreu, Almeida, Silva et al. (2016); Lowenstein-Barkai and Lev-On (2018); Vinayagamoorthy et al. (2016)

ATMs (Regal et al., 2013), public displays (Cerny & Donahoo, 2016; Sahibzada et al., 2017), or game experiences (Emmerich, Liszio, & Masuch, 2014; Pagno et al., 2015; Weißker et al., 2016).

Mobile devices are typical second screens

Mobile devices are typically seen as second screens[6], often mentioned with *laptops* or *desktops*[7], or *Internet access* in this context[8]. Laptops are also often used as test devices in studies to facilitate the development of functional prototypes of a second screen application (Angeluci et al., 2017; Basapur et al., 2011; Basapur et al., 2012; Obrist et al., 2009; Pagno et al., 2015). Another aspect that is often mentioned in this context is the simultaneous use of both devices[9].

2.2.2 Discussion of Results on Second Screen

The review of the literature confirmed an imprecise use of the term *second screen*. Most authors have only a vague idea of the concept, which is mostly very similar, but not exactly defined.

All results indicate a high distribution of second screening

The different results in literature on general second screen activity and the amount of time spent with second screen lead to the conclusion, that second screening is highly distributed and therefore relevant, but still not well understood (Holz et al., 2015, p. 94). Methodological hurdles and strong fluctuations in

[6] Anstead et al. (2010); Angeluci et al. (2017); Abreu et al. (2013); Abreu, Almeida, Silva et al. (2016); Anstead et al. (2014); Badii et al. (2015); Bernhaupt et al. (2013); Brown et al. (2014); Courtois and D'heer (2012); Cunningham and Weinel (2015); D'heer et al. (2012); Doughty et al. (2012); Duong et al. (2012); Geerts et al. (2014); Menychtas et al. (2015); Morales and Shekhawat (2013); Mosqueira-Rey et al. (2017); Mu et al. (2015); Neate et al. (2016); Neate et al. (2017); Pagno et al. (2015); Simon et al. (2013); Stauff (2015); Vinayagamoorthy et al. (2016); Nagel (2016)

[7] Anstead et al. (2010); Brown et al. (2014); D'heer et al. (2012); Neate et al. (2016); Simon et al. (2013); Johnen and Stark (2015); Gil de Zúñiga et al. (2015)

[8] Busemann and Tippelt (2014); Cerny and Donahoo (2016); Doughty et al. (2012); Duong et al. (2012); Gil de Zúñiga et al. (2015); Holz et al. (2015); Johnen and Stark (2015); Lowenstein-Barkai and Lev-On (2018)

[9] Almeida et al. (2015); Angeluci et al. (2017); Busemann and Tippelt (2014); Cunningham and Weinel (2015); Gil de Zúñiga et al. (2015); Johnen and Stark (2015); Morales and Shekhawat (2013); Mosqueira-Rey et al. (2017); Mukherjee and Jansen (2015); Vanattenhoven and Geerts (2017); Neate et al. (2017); Lowenstein-Barkai and Lev-On (2018); Vinayagamoorthy et al. (2016); Ziegler (2013)

different age groups make it difficult to make an accurate estimate, but the bottom line is that all results agree on the high relevance of second screen activity[10].

No limitation to content-related use

Most of the literature mentioning the aspect of *content-related* use, suggest that any type of activity on a second device should be included as second screening[11]. This is also due to the fact that all results agree that content-unrelated use is much more widespread than content-related use (Busemann & Tippelt, 2014; Deloitte, 2016; D'heer et al., 2012; Holz et al., 2015; Johnen & Stark, 2015; Shokrpour & Darnell, 2017). Another factor is the difficulty to clearly separate the two activities, especially in cases that may relate to both types, such as the use of *Twitter* on a mobile device (Johnen & Stark, 2015). Therefore, second screening should include both related and unrelated activities on the additional device.

Inclusion of any screened device

Although the most frequently cited example of second screening consists of a *mobile device* and a *television set*, the term should not be reduced to this scenario alone. With the currently available variety of devices of potential first and second screens, such as televisions, mobile phones, tablets, laptop, desktops, gaming devices, projectors, public displays such as venue screens in hotel rooms, meeting halls, arenas, elevators, stores (Cerny & Donahoo, 2016), and ATMs opening up a wide range of application possibilities, it is difficult to draw a clear line. Even if an Internet connection is available on most second screen devices, it is not a suitable criterion for this activity, as it could lead to an inconsistent use of the term if a device has the ability to access the Internet, but not currently due to a bad connection, network fault, or user preference. Therefore, and in order to enable and encourage further novel usage scenarios and applications, all of the devices mentioned above and each other screened device are considered as possible first and second screens.

Physical separation of first and second screen

In this context is the clear physical separation of the first and second screen an important aspect (Cunningham & Weinel, 2015; Gil de Zúñiga et al., 2015;

[10] The Nielsen Company (2017); Cunningham and Weinel (2015); Johnen and Stark (2015); Deloitte (2016); Shokrpour and Darnell (2017), Holz et al. (2015, 2015)

[11] Menychtas et al. (2015); Almeida et al. (2015); Anstead et al. (2014); Brown et al. (2014); Busemann and Tippelt (2014); Cunningham and Weinel (2015); D'heer et al. (2012); Johnen and Stark (2015); Mosqueira-Rey et al. (2017); Neate et al. (2016); Negenman et al. (2016); Vanattenhoven and Geerts (2017)

Holz et al., 2015; Johnen & Stark, 2015; Mukherjee & Jansen, 2015). For example, a computer with two screens is not considered second screening due to psychological differences in the use of two different devices and a second window (Johnen & Stark, 2015; Yeykelis, Cummings, & Reeves, 2014). The aspect of separated physical devices is also the main disambiguation to *multi-screening*, which represents a collective term for all the different forms of using more than one screen in general.

Numbering of first and second screen

In the reviewed literature, the mobile device was consistently regarded as the *second* and the television device as the *first* screen, but no concrete argument was found for this numbering. This distinction might have originated from the order of appearance, e.g. the television was present in living rooms before mobile devices. The size of the screens and the continuity of television compared to the more volatile use of mobile devices might be other another reasons for this counting. Other terms such as *dual screen* without ranking the different screens could resolve this argument, but are rarely used (Basapur et al., 2011; Neate et al., 2016; Neate et al., 2017; Robertson et al., 1996; Vaccari, Chadwick, & O'Loughlin, 2015) and the lack of distinctiveness between the screen also creates new problems. In the end, it is also not important which screen is considered *first* and *second*, as long as these terms are used uniformly to allow a clear distinction. Therefore, to simplify matters, the larger device (television) is considered as first and mobile devices as second screen, as is each additional device (Anstead et al., 2014).

2.2.3 Definition of the Term Second Screen

Identified aspects of second screening

The previous sections presented the results of the SRL regarding the different interpretations of the term second screen and discussed the associated aspects. The resulting conclusions are presented here with the following aspects regarding the term *second screening*:

- Any type of *screened device* is a potential first or second screen, which includes a wide variety of devices, but mostly refers to a television as first and a mobile device as second screen.
- Any kind of *media content* on both devices is considered as second screen activity.
- Both screens must be physically separated from each other.
- Both devices must be used simultaneously.
- Additional devices are also referred to as second screens.

Definition second screening

Cunninngham & Weinel (Cunningham & Weinel, 2015, p. 228) description covers almost all of the aspects mentioned and is extended to specifically included *laptops* as second screen devices and *any* kind of content on the additional device to create the following definition:

> *The act of second screening involves the use of an additional media screen such as provided by a mobile phone, tablet, or laptop, to consume any kind of content alongside a primary screen such as a TV.*

Differentiation from other terms

Multi-screening is a generic term that covers any activity involving more than one screen, including devices, such as computers, with multiple connected screens. This also includes all *second screen activity*, which encompasses both content-related and unrelated use. *Dual screening* is classified on the same level as second screening activity, but is used less frequently. Dedicated *second screen* and *companion applications* are always content-related and provide added value such as synchronized information, social components, gamified content, or control functions. These benefits are discussed in more detail in the next section in the form of the *ISGCO* classification.

2.3 Classifications for Second Screen Applications

In addition to a detailed description of what distinguishes and characterizes the term *second screen* presented in the previous section, two classifications have been created describing the use and implementation in this context, which are described below.

2.3.1 A Content-Related (ISGCO) Classification of Second Screen Applications

Existing classifications have drawbacks

Several approaches have been found in the SRL to classify the different uses of second screens. However, all existing solutions are considered to have drawbacks, such as having been created some time ago and needing to be adapted to current developments, being designed as a by-product and are therefore less mature, or not considering all relevant aspects. Therefore, the categorizations found are presented, discussed, and synthesized in the following to form a basis with the results of the SRL for a well-founded content classification of second screen applications.

2.3.1.1 *Previous Categorizations of Second Screen Applications in Literature*

Transfer is an unfit second screen category

The most prominent and cited categories[12] for second screen activity are by Cesar, Bulterman et al. (2008) (Cesar et al., 2008): *control*, *enrich*, *share* and *transfer*. The first three categories were adopted for the here introduced *ISGCO* classification, the *transfer* aspect, however, is interpreted differently. It refers to the possibility of second screen applications to *take* content along from a first screen, for example to continue watching a video on a mobile device when leaving a room. This is without a doubt a benefit of such applications, but the simultaneous usage of a first and second screen stops in this scenario, hence it is no longer considered *second screening* and therefore an unfit category for such applications.

Content based categories are better suited

Morales and Shekhawat (Morales & Shekhawat, 2013) name three categories of typical activities with second screens. *Social sharing*, *gamification and extra*, and

[12] Geerts et al. (2008); Doughty et al. (2012); Tsekleves et al. (2009); Geerts et al. (2014); Murray et al. (2012); Abreu et al. (2013); Obrist et al. (2009); Anstead et al. (2010); Martin and Holtzman (2010); Holz et al. (2015)

expanded experience. *Social sharing* is interpreted by the authors in a similar way to this work. However, the sharpness of distinction between *gamification and extra* and *expanded experience* is considered as too imprecise in this categorization. These categories were created by its kind of interaction: *Human-Human* (hh), *Human-Machine* (hm) and *Machine-Human* (mh), which is sensible from a technical view, but could lead to problems with its applications. For example, it might be difficult to understand in a media library application why *behind-the-scenes looks* and *deleted scenes* are classified under *gamification* and *explore the cast* and *related content* under *extended experience*. Therefore, as with the other found approaches (Cesar et al., 2008; Cruickshank et al., 2007; Doughty et al., 2012; Geerts et al., 2008; Ziegler, 2013), categorizing the second screen activity by *content* and *use* seems easier to comprehend.

Two categories are unfit for a precise classification

Tsekleves et al. (2009) propose two categories of second screen applications: one for the *control* of the content on the first screen, and a second one that includes *enhanced interaction*, such as quizzes, games, or voting, and social TV components. The benefit of additional information is not mentioned by the authors in this context. The rather broad differentiation in two categories is unfit for a precise classification, but nonetheless offer the named features great value for second screen applications and are therefore incorporated with a finer distinction in the *ISGCO* classification.

Similar categories to the ISGCO classification

Ziegler (2013) identifies four categories of second screen applications related to the content of the first screen: *information*, *social*, *recommendations* and *further involvement with the first content*. These categories are similar to those of the here introduced ISGCO classification, the first two are a direct match, recommendations is considered as part of *social* or *information*, depending on their origin, and the content of the latter named category is consistent with that of the *game* category. Besides these categories, the author considers another content-unrelated group of applications, which enable *control* functionalities on the first screen. These *control* functions are not seen separately in ISGCO classification, because these aspects can relate to both the device and the content, as for example in games, and is therefore treated equally with the other categories.

Most of the cited literature name the same aspects of second screen applications directly or semantically as postulated in this work: *information*, *social*, *games* and *control*. Additionally the category *other* was added for features like *shopping*, *advertisement*, or *future* features which are hard to assign to the other categories. The categorizations of second screen applications found in literature are summarized in Table 2-2, whereby the repeated occurrence of the first four categories of the *ISGCO* classification notable.

Repeated occurrence of ISGCO categories

Reference	Information	Social	Games	Control	Other
Cesar et al., 2008	1	2		3	
Doughty et al., 2012	1	2		3	
Geerts et al., 2008	1	2		3	
Morales & Shekhawat, 2013	2/3	1	2	2	
Tsekleves et al., 2009		1	1	2	
Ziegler, 2013	1	1	1	2	

Table 2-2: Direct or semantic match of ISGCO classification with the categorizations found in literature. The numbers refer to the classification proposed by each author.

2.3.1.2 *The ISGCO Classification*

Most categories in the literature are created according to the authors' experiences with second screen applications and lack of further argumentation. The *ISGCO* classification is to be understood as a summary of the previous approaches, which came to similar conclusions, but lacked completeness. With the previous introduced preliminary work and by confirming the identified categories through a structured analysis of the relevant literature and commercial application, the *ISGCO classification* is introduced as a content driven classification for second screen applications, named after its contained categories:

ISGCO classification for second screen applications

1. *Information*: Additional content provided on the second screen.
2. *Social*: Interaction with other users in form of chats, social networks, or the consumption and creation of additional content (also referenced as *social TV* aspects).
3. *Games*: Further involvement with the first screen content, especially in form of voting, quizzes, or other gamified content or enrichments.
4. *Control*: Control features on the second screen towards the first content.
5. *Other*: Shopping or advertisement features.

Distribution of the categories

The applications found in the SRL and the market analysis have been classified into the categories identified here to get an estimate regarding their frequency of appearance. *Additional information* (I) was found to be the most widespread enhancement of second screen applications: every commercial application analyzed and most of the applications found in the SRL offered this feature, followed by *control* features (C). A major factor here is the high number of remote control and media library applications available, similar to *Netflix*, *YouTube* or *Amazon Prime Video*, but some of the work found suggests more unconventional approaches such as for ATMs (Regal et al., 2013) or movie theaters (Cunningham & Weinel, 2015). *Social (S)* and *game (G)* features are less common than the other categories, but are still found in various applications. No application belonging to the *other* category (O) was identified, which is intended for innovative features such as the ability to directly purchase items associated with the current content of the first screen and other features of future applications. The distribution of the classified features of second screen applications in research and commercial application are in the same order as shown in Figure 2-2.

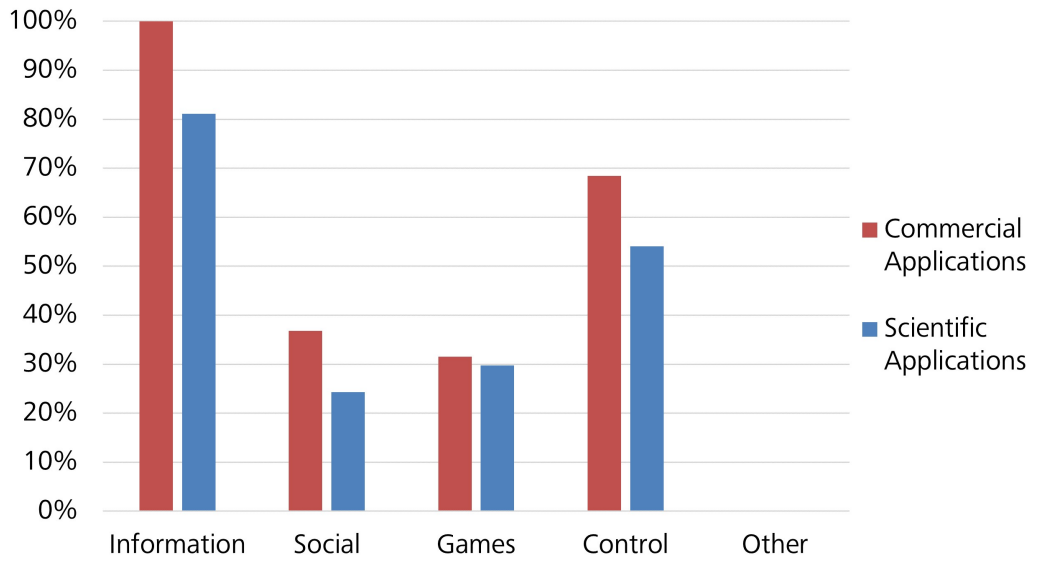

Figure 2-2: Distribution of identified categories of second screen enhancements in research and commercial applications.

2.3.2 A Technical Classification of Second Screen Applications

Previous technical classification approaches

The previously introduced aspects of second screen activity refer exclusively to its content dimension. However, there are several approaches on how to implement these benefits on a technical level found in literature and current applications. There are fundamental differences between establishing a connection directly (Anstead et al., 2010; Cruickshank et al., 2007; Neate et al., 2017), indirectly (Martin & Holtzman, 2010; Mu et al., 2015; Murray et al., 2012), or in timed intervals (Basapur et al., 2011; Basapur et al., 2012; Brown et al., 2014). Although the results of the different approaches often look similar, their differentiation on the technical level is important, because they come with different advantages and disadvantages in functionality and usability. Two approaches were found in literature on how to systemize these implementations of second screen applications:

Differentiation between levels of interactivity

Bernhaupt et al. (2013) propose a classification referring to the *interactivity* and *synchronization* of second screen applications, but do not consider the technical dimensions. These factors are important in this respect and are therefore taken into account in the here proposed technical classification, as are the different levels of interactivity.

Insufficient distinctiveness of the classification

Mosqueira-Rey, Alonso-Ríos et al. (2017) identify three types of interaction with second screen applications: *Synchronized TV Apps*, *Companion TV Apps*, and *Interactive TV Apps*. *Companion applications* are seen as source of additional information, *synchronized applications* are connected with the first screen to offer remote control features, and *interactive applications* offer a more complex interaction between the two screens such as games. These features can only be assigned to one category, which causes problems for applications that contain more than one of these aspects, such as information and control aspects. Although this approach represents a possible classification, its discrimination accuracy can still be further developed, which is why it is used as the basis for the technical classification presented here.

On the base of these two previous classifications, the result of the SRL, and the analysis of second screen applications, the classification in Figure 2-3 was created to distinguish the technical approaches for second screen applications and its relation to general second screen activity:

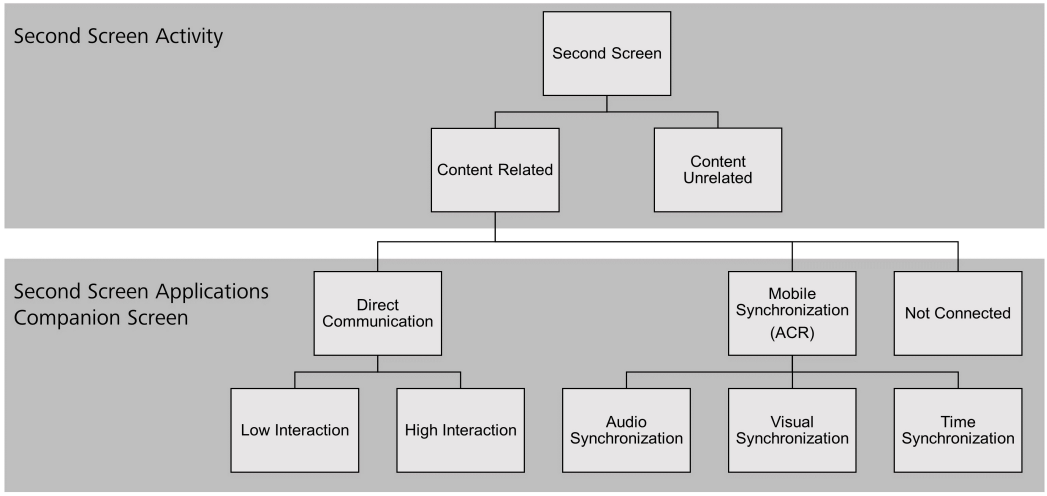

Figure 2-3: Technical classification for second screen applications in relation to general second screen activity.

2.3.2.1 *Classification of Second Screen Activity*

Content related and unrelated second screen activitv

The top nodes of the classification refer to the general second screen activity, distinguishing between content-related and content-unrelated use, included to provide a better overview of the general context. As discussed in section 2.2.1.2, *content-unrelated* second screening is any activity on a secondary device without direct connection to the current first content, such as emailing, online shopping, or internet browsing and is far more distributed than content-related activity (Busemann & Tippelt, 2014; Deloitte, 2016; D'heer et al., 2012; Holz et al., 2015; Johnen & Stark, 2015; Shokrpour & Darnell, 2017). *Content-related* use, on the other hand, refers to activities such as looking up additional information, participating in social networks, or in the form of dedicated second screen applications. It should be noted that all these examples can also be assigned to the opposite category of second screen activity depending on the context, e.g. e-mailing can be *content-related* and participating in a social network can be *unrelated*. However, all dedicated second screen applications are related to the first screen content, otherwise they would not be considered as such, but as regular mobile applications.

2.3.2.2 *Classification of Second Screen Applications*

Distinction second screen applications

There are several approaches on how to realize the benefits of *second screen* or *companion* (*screen*) applications shown in the lower part of the classification in Figure 2-3, distinguishing between *directly communicating*, *mobile synchronization* and *not connected* applications, which are presented in the following.

Directly Communicating Applications

Distinction of different levels of interactivity

Directly communicating second screen applications offer the greatest potential of these approaches, as the first screen is aware of a potential second screen. This allows both application parts to communicate bidirectionally and has thereby the highest level of synchronization between the different screens, because the application was explicitly designed for this interactive second screen experience. In this context, a distinction is made between different provided levels of interactivity (Bernhaupt et al., 2013; Mosqueira-Rey et al., 2017): a *lower* level for remote control features and a *higher* level for more complex interactions such as games.

Applications like *Netflix*, *YouTube*, and *Amazon Prime Video* are well-known examples of second screen applications with low interaction as they offer remote control features on the additional device such as content selection and control. Functionalities beyond this scope are considered to be *highly interactive* and are also referred to as *dynamic applications* (Mosqueira-Rey et al., 2017; Pagno et al., 2015). Disadvantages of directly communicating second screen applications are the dependence on technical infrastructure such as *smart TVs*, *Chromecasts, Fire TV boxes* or in many cases a local network connection for users. Developers often have to undergo a redundant development process for multiple of these solutions to reach an acceptable target group size, which complicates the realization of such applications. This problem is also addressed by the later introduced *2ndS SDK* for second screen applications (cf. Chapters 3 & Chapter 4).

Mobile Synchronizing Applications (ACR)

Applications based on the *mobile synchronization* approach try to provide the benefits of second screen applications without creating too much effort for developers and technical dependencies for users, but work with the existing infrastructure. Thereby the mobile device tries to *automatically recognize* the *content* (ACR) on the first screen by the *auditory* or *visual* information of the content or the *time* of the broadcast and thus synchronize the second with the first screen. This process is one-sided from the second screen as, which opens up fewer possibilities, such as control features, compared to *directly communicating* applications in which both application parts cooperate.

Audio synchronization

A*udio synchronization* can be either the recognition of an inaudible signature (*audio watermarking*) (Angeluci et al., 2017; Holmes et al., 2012) or the *listening* to the actual content (*audio fingerprinting*), such as *Shazam* or similar services (Cunningham & Weinel, 2015, p. 231). Audio watermarking requires the embedding of a signal in the content beforehand and therefore the co-operation of producers, which may be difficult to obtain for a majority of mainstream content. Audio fingerprinting might be a viable option for an accurate synchronization, however the processing of all relevant contents and current patents could lead to problems in this respect (Cunningham & Weinel, 2015, p. 230).

Visual synchronization

Visual synchronization is mostly implemented with scannable QR-codes (Angeluci et al., 2017; Simon et al., 2013; Ziegler, 2013), but also less frequently with visual fingerprinting techniques (ProSiebenSat.1 Digital GmbH, 2018). QR-codes can enable a fast and efficient synchronization, but might negatively impact the viewing experience because the displayed codes cover part of the first screen content and the manual scans can break the immersion, especially if users have to stand up to do so (Angeluci et al., 2017, p. 7525).

Time synchronization

However, most applications associated with this approach are synchronized with *time* due to their comparatively low development and usage effort. This is achieved less frequently by *manual* synchronization (Almeida et al., 2015; Basapur et al., 2011; Basapur et al., 2012), and in most cases using the current time of use (Brown et al., 2014; Neate et al., 2015b; Neate et al., 2016). This allows users to participate in live quizzes, surveys or direct feedback. The main drawback of this approach is the lack of flexibility due to the dependence on fixed broadcasting times and the inability to interrupt them. Additionally is the functionality often limited to live or first transmissions of contents. This thus enabled shared experience during this type of transmission is however unique for all second screen applications.

Not-connected applications

Not-connected applications

Not-connected second screen applications provide benefits that are not synchronized with the first screen, but are still content-related such as additional information on actors, characters, or locations. This type of application requires the least development effort and technical infrastructure requirements, because first and second screens are completely independent from each other and thus provide the least functionality and least positive experience.

2.3.2.3 *Application of the Technical Classification*

Low interaction application have the highest distribution

After creating the technical classification, it was applied to the applications found in the SRL (SA) and in commercial use (CA). The most common type of application among the two sources are *low interaction* applications (57.8 % CA, 40.5 % SA) that provide control functions such as content selection and playback control.

In the literature, several prototypes (27.0% SA) with a more complex interaction between the two screens are presented, which are here referred to as *highly interactive* applications. This application type has great potential for providing novel experiences such as games with a shared first screen and private information on the second screen (Emmerich et al., 2014; Pagno et al., 2015) or quiz features that are directly interacting with the current content (Anstead et al., 2010; Negenman et al., 2016). Due to their innovative nature and complexity, and thereby high development effort, this application type are less common in commercial applications (10.5 % CA), but may become more relevant in the future. *Audio synchronization* approaches have been found in literature (8.1 % SA), but not in commercial applications, and *visual synchronization* is unusual in both sources (5.2 % CA, 2.7 % SA). *Time-synchronized* applications are popular in commercial and scientific applications due to their low effort character in development and use (15.7 % CA, 18.9 % SA). *Not-connected* second screen application are in general uncommon (10.5% CA, 2.7 % SA), potentially because of the limited value offered by this type of applications compared to the other approaches. Figure 2-4 shows the distribution of scientific and commercial second screen applications according to the technical classification presented here.

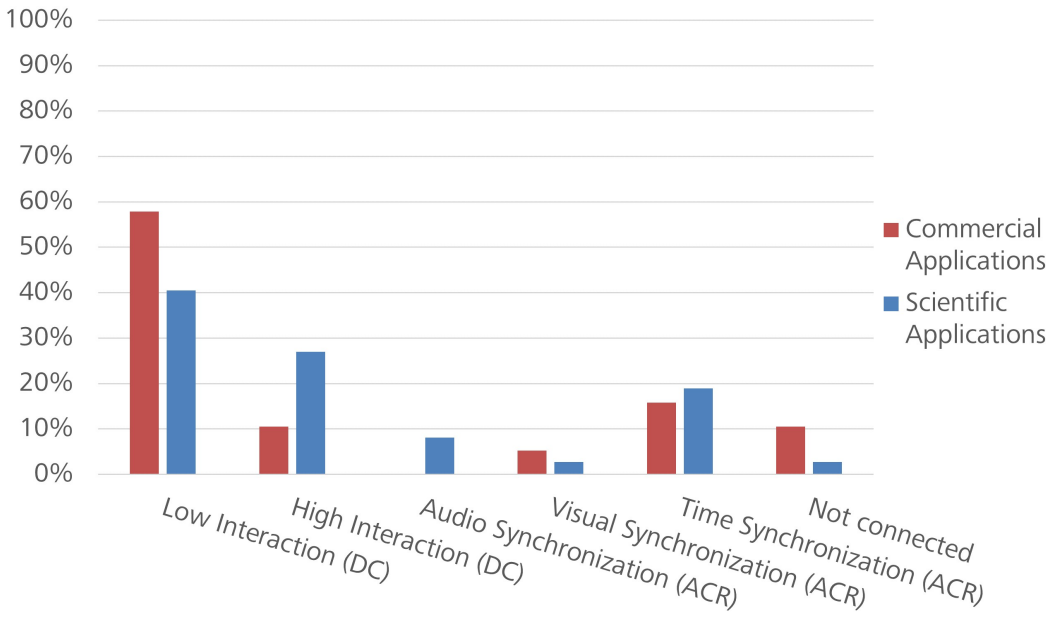

Figure 2-4: Distribution of scientific and commercial second screen applications according to the here presented technical classification.

Table 2-3 provides a description of the analyzed commercial application with the associated benefits according to the *ISGCO* and *technical* classification. The high proportion of *low interaction* application providing *additional information* and *control* aspects within these applications was already shown in Figure 2-3 and Figure 2-4. The following table underlines these results:

Name	Description of Commercial Second Screen Application	Categories	Classification
(Amazon Mobile LLC, 2018; Google LLC, 2018; Netflix, 2018; Tubi TV, 2018)	Media library application – selecting and controlling content on second screen.	I; C	Low Interaction
(Erstes Deutsches Fernsehen, 2018a)	Quizzing alongside live show with additional information.	I; G	Time Synchronization
(ARD-aktuell, 2018)	News content with commentary and media library functions.	I;S;C	Low Interaction
(RTL2 Fernsehen GmbH & Co. KG, 2018a, RTL2 Fernsehen GmbH & Co. KG, 2018b)	TV show companion applications – additional information, chat and voting features.	I; S; G; C	High Interaction
(digame GmbH, 2018)	Time synchronized information and voting on live event.	I; G	Time Synchronization
(ProSiebenSat.1 Digital GmbH, 2018)	Live augmented additional information and interaction possibilities.	I; G	Visual Synchronization

Name	Description of Commercial Second Screen Application	Categories	Classification
(miniMapps, 2018)	TV show background information on characters and locations, manually synchronized for each episode.	I	Not Connected
(Erstes Deutsches Fernsehen, 2018b)	Background information on episodes and characters. Live voting during first broadcast.	I; S; G	Time Synchronization
(Twitch Interactive, 2018)	Media library application – live chat on second screen additional to content selection and controlling.	I; S; C	Low Interaction
(UEFA, 2018)	Statistics and videos to sports events	I	Not Connected
(Microsoft Corporation, 2018; PlayStation Mobile Inc., 2017)	Control and chat features for a video game console	I; S; C	Low Interaction
(ARD.de/SWR, 2018; Zattoo Europa AG, 2018; ZDFonline, 2018)	Media library application – selecting and controlling TV content on second screen with additional program information.	I;C	Low Interaction

Table 2-3: Description, categorization, and classification of analyzed commercial second screen applications according to the technical and content classification.

Combination technical and ISGCO classification

The ISGCO classification of second screen applications can also be combined with this technical classification. For example, c*ontrol* features are typical and limited to *directly communication* applications, *information* and *social* components are common among all application types, and game aspects are untypical for low interaction second screen applications.

2.4 Collection of Findings on Second Screen Behavior in this Dissertation

Collection of insight from different conducted studies

In addition to the findings on the use of second screens described in the literature, the later in this work described studies generated insights in this regard. This section summarizes these results on second screen behavior gained by various conducted studies, such as the *cultural probe* on second screen behavior (cf. Chapter 6.2.1), the *online survey* for validating the raised second screen application components (cf. Chapter 6.2.2), the *two eye-tracking studies* on attention behavior (cf. Chapter 7.2 & Chapter 7.3), the *user tests* for evaluating the design guidelines (cf. Chapter 8.2.3), and the *validation* of the heuristic checklist (cf. Chapter 9.4). The background, methodology, and main findings of each study are covered by the referenced sections; the more general findings on second screening are collected here for better overview. The results of the different studies are not summarized, but presented individually, as they were collected under different circumstances.

Frequency and trigger of second screen use

Of the 110 recorded television events in the *cultural probe* (cf. Chapter 6.2.1), only four (3.6%) were observed without the use of a second screen. It should be noted that a television *event* can also cover a longer period of time, as it measures one consecutive use of a television. In most cases, participants have used a second screen between one and five times during one event, as shown in Figure 2-5. Triggers for this were 70 times signal from the mobile phone, 43 times *other* triggers like looking at the time, 31 times initiated from the user himself like a reminder, and 10 times because of the content of the television. Further triggers were advertising (8), boredom (5), desire for entertainment (4), and habit (4).

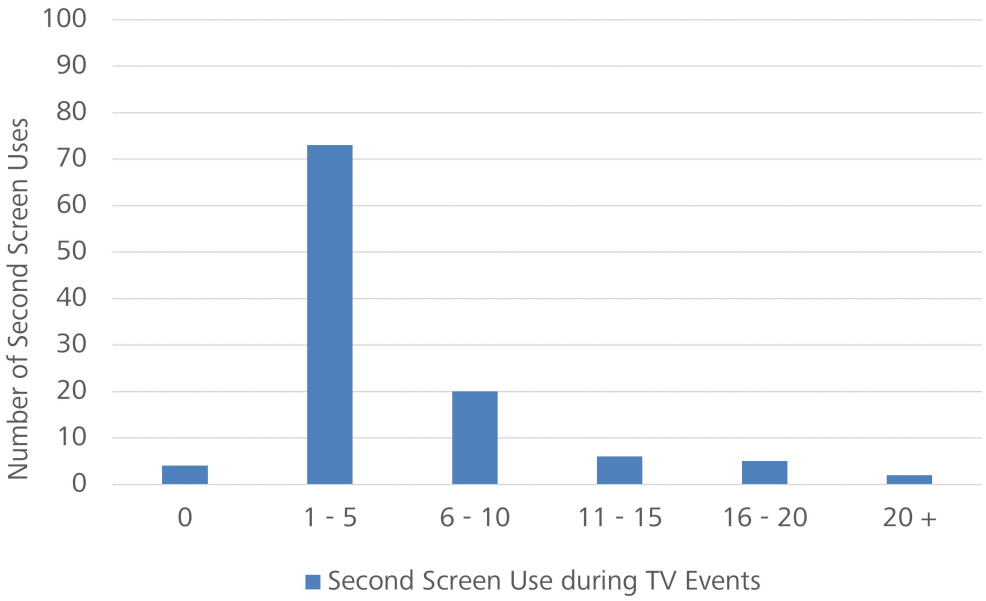

Figure 2-5: Frequency of second screen use during single television events surveyed in the cultural probe.

Self-assessment of second screen activity

In the self-assessment of the participants regarding their second screen behavior, which was collected in the preliminary survey of the individual conducted studies, mixed results were obtained. The participation on general second screen activity confirmed with 56%[13], 80%[14], and 95%[15] even though each test provided a prior clarification of what was understood as *second screening*. These results are consistent with those described in literature, where similar deviations were observed in the self-assessment of second screen activity (cf. Chapter 2.2.1.1). The most popular activities[14][15] in this context are *social networking*, *gaming*, and accessing *additional information* in this order in the frequency of naming.

Experience second screen applications

With regard to the use of explicit second screen applications, 23%[16], 25%[15], 29%[17], 30%[14], and 64%[13] of the respondents had experienced in the respective studies. These results indicate, with one exception, that the spread of second screen applications is not yet well advanced. The most frequently used applica-

[13] Study on the evaluation of the concepts in the design guidelines (n=36) (cf. 8.2.3).
[14] Second eye-tracking study on attention behavior (n=20) (cf. 7.3).
[15] Validation study of the heuristic checklist (n=20) (cf. 9.4).
[16] First eye-tracking study on attention behavior (n=30) (cf. 7.2)
[17] Online validation survey of second screen components (n=56) (cf. 6.2.2)

tions were *YouTube*, *Netflix* and *Amazon Prime Video*, which are media library applications, classified as low interaction applications, and have the highest overall distribution of second screen applications (cf. Chapter 2.3.2). The online study[17] also found that 55% of participants are interested in such applications compared to 29% who already use them. This indicates a lack of a suitable solutions and current hardware limitations, what is further discussed in Chapter 4.1 in form of the *double multi-platform problem*.

2.5 Summary Clarification on Second Screen

Applied methodology

This chapter provides a unified clarification on the term *second screen* and its characteristics. To this end, a systematic literature review of 65 relevant publications and an analysis of 19 commercial applications has been conducted to collect and abstract different concepts scattered across the different sources.

Clarification second screening

The extracted aspects of *second screening* have been synthesized, discussed, and reflected upon in order to provide a well-founded clarification on what *second screening* precisely is. The resulting definition includes each *screened device* and *any kind of content* used *simultaneously* on two *physically separated* screened devices.

Created classifications

Two classifications have been created in order to provide a precise description of the different aspects of use and technical characteristics of second screening. The *ISGCO* classification refers to the identified content-related benefits of second screening, namely *information*, *social*, *gaming*, *control*, and *other*. The second classification addresses the technical approaches on how to provide these enhancements and distinguishes between *directly communicating*, *mobile synchronizing*, and *not connected* applications in relation to general second screen activity. The applications found in literature and commercial use were categorized according to these classifications to provide an estimate on the current distribution of the different second screen application types.

Findings on second screen activity in this work

Furthermore, the results concerning second screen usage from the studies carried out were presented here for a better overview. These findings confirm the findings from the literature on the lack of enforcement of second screen applications and the general, quite high activity of second screening, but also show similar deviations.

Part II – Multi-Platform Second Screen SDK

3 Design Approach of the Second Screen SDK

This chapter offers a theoretical reflection on the development of the 2ndS SDK beyond the scope of second screening, which was discussed in detail in the previous chapter as it the main theme of this work. In this chapter, an overview of *cross-platform software development* and *design science research* is given before this approach is applied in the next chapter in the development of the 2ndS SDK.

3.1 Cross-Platform Development

Software platform & heterogeneity

Sommerville (2011, p. 10) describes the *heterogeneity* of software systems, e.g. the requirement to support different types of devices, as one of the general issues of software development. This heterogeneity is caused on the one hand by the increasing demand for simultaneous support of several device types, such as computers and mobile devices, and on the other hand by several platforms within these types, such as *iOS* and *Android* for mobile devices. Although this problem has been amplified in recent years by the increasing number of available devices, the parallel existence of multiple *platforms* within one device type is a known problem in software development. A *software platform* is understood as the environment in which the software is executed, typically consisting of operating system, database, middleware, and other application systems (Sommerville, 2016, p. 57).

Fragmented platform landscapes

A well-known example of this is the fragmented landscape of desktop computer operating systems, where *Microsoft Windows*, *macOS* and *Linux* have coexisted for decades, although *Microsoft Windows* is by far the most widespread. Another example are mobile operating systems, in which initially a large number of providers emerged such as *Window phone*, *Ubuntu*, *Tizen*, *Firefox OS*, *BlackBerry* OS, *Nokia Ovi*, *Symbian*, *Android*, and *iOS* (Hammoudeh S Alamri & Balsam A Mustafa, 2014, p. 2; Wasserman, 2010, p. 397). In the last ten years, the latter two mobile operating systems have established themselves on the mobile market and together have almost complete market coverage, with *Android* having a stronger presence of around 85% (IDC, 2018). This pattern, in which initially many providers compete for a new market and over time a few prevail, seems to be the

rule with software platforms. The problem of platform fragmentation applies to many domains, such as *browsers* (Choudhary, 2014, p. 642), *sensor networks* (Brzozowski, Salomon, Piotrowski, & Langendoerfer, 2011, p. 7), but also *smart TV devices*, which are a relatively new phenomenon and are still in the middle of this process, with many provider competing for market coverage (cf. Chapter 4.1.2).

Problems caused by fragmentation

The development of software for this variety of platforms causes several problems, in particular the redundant development of the same application for several platforms in order to make it accessible to as wide a user group as possible[18]. The different targeted platforms require mostly different programming languages[19], development tools (*IDEs*)[20], SDKs[21], distribution channels[22], and the consideration of different hardware components[23] and design guidelines[24] which potentially conflict with the original design. These factors not only lead to rising costs and effort in development[25], but also in testing and maintenance (Choudhary, 2014, p. 642).

Cross-platform development

Therefore, approaches have been developed to deploy applications on multiple software platforms with the same code base to address the problems caused by the fragmented platform landscape known as *cross-platform development* (Charkaoui et al., 2014, p. 188). The challenge with these approaches is to find a solution that allows applications to be deployed across different platforms with a single

[18] Brzozowski et al. (2011, p. 7); Choudhary (2014, p. 643); Xanthopoulos and Xinogalos (2013, p. 213); Gaouar, Benamar, and Bendimerad (2015, p. 1); Hammoudeh S Alamri and Balsam A Mustafa (2014, p. 1)
[19] Charkaoui, Adraoui, and Benlahmar (2014, p. 188); Gaouar et al. (2015, p. 1); Xanthopoulos and Xinogalos (2013, p. 213)
[20] Charkaoui et al. (2014, p. 188); Wasserman (2010, p. 397); Xanthopoulos and Xinogalos (2013, p. 213)
[21] Hammoudeh S Alamri and Balsam A Mustafa (2014, p. 1); Gaouar et al. (2015, p. 2); Latif, Lakhrissi, Nfaoui, and Es-Sbai (2016, p. 1)
[22] Latif et al. (2016); Xanthopoulos and Xinogalos (2013); Jobe (2013)
[23] Brzozowski et al. (2011, p. 7); Charkaoui et al. (2014, p. 188)
[24] Brzozowski et al. (2011, p. 7); Hammoudeh S Alamri and Balsam A Mustafa (2014, p. 2); Wasserman (2010, p. 399)
[25] Brucker and Herzberg (2016, p. 73); Charkaoui et al. (2014, p. 188); Gaouar et al. (2015, p. 1); Wasserman (2010, p. 400); Xanthopoulos and Xinogalos (2013, p. 213); Jobe (2013, p. 32)

SDK and achieves the same performance as native applications (Latif et al., 2016, p. 1). The best known example for these approaches are web applications, which offer a *write once run anywhere solution* with the same code base, but still need to be tested and adapted for different browser platforms due still occurring differences in the interpretation (Choudhary, 2014, p. 643). Nevertheless, this approach is currently the most advanced to create a unified and satisfying solution on different platforms including desktops and mobile browsers, with limitations in terms of performance and other drawbacks elaborated in the following.

Cross-platform drawbacks

A large part of current research relates to cross-platform approaches for mobile applications, where the above-mentioned problems of redundant development being particularly pronounced. In order to cope with this diversity, different approaches are distinguished[26], but all are considered to have drawbacks such as security challenges[27], poor performance compared to native applications[28], missing availability of native features[29], and an inclination to be more prone to user complaints regarding usability and reliability (Mercado et al., 2016, p. 46).

Conclusion cross-platform development

The prevailing opinion in literature on cross-platform solutions is a recommendation when time and cost are limited, but all existing approaches are still associated with certain drawbacks compared to native solutions. This applies in particular to performance-intensive scenarios; for applications with less complex content cross-platform approaches can be a sensible alternative (Jobe, 2013, p. 32). But overall, most applications are still developed using native approaches and only a small percentage of cross-platform solutions are able to create a completely satisfactory experience (Brucker & Herzberg, 2016, p. 10; Latif et al., 2016, p. 5). The desire to defragment and optimize (mobile) application development by cre-

[26] Latif et al. (2016, p. 2); Latif, Lakhrissi, Nfaoui, and Es-Sbai (2017, p. 1); Gaouar et al. (2015, p. 1); Brucker and Herzberg (2016, p. 1)
[27] Brucker and Herzberg (2016, p. 2); Wasserman (2010, p. 398); Shehab and AlJarrah (2014, p. 8)
[28] Xanthopoulos and Xinogalos (2013, p. 213); Diep, Tran, and Tran (2013, p. 294); Charkaoui et al. (2014, p. 191); Wasserman (2010, p. 398); Hammoudeh S Alamri and Balsam A Mustafa (2014, p. 1); Mercado, Munaiah, and Meneely (2016, p. 48)
[29] Charkaoui et al. (2014, p. 191); Wasserman (2010, p. 398); Hammoudeh S Alamri and Balsam A Mustafa (2014, p. 1)

ating a single application that works everywhere with the same qualities as a native approach is still a difficult goal to achieve, but remains as attractive as ever (Charkaoui et al., 2014, p. 188). This goal is also pursued in this work by the application of a *design science approach* to develop a flexible solution to cope with the heterogeneity of second screen development in form of the 2ndS SDK.

3.2 Design Science as Research Procedure

Design science

In contrast to *empirical research*, which describes, explains, and predicts the world, *design science research* changes and improves it by solving specific problems through the development of artefacts. These artifacts aim to help people to fulfill their needs, overcome problems, or open up new opportunities and thus generate knowledge about them, their use, and their environment (Johannesson & Perjons, 2014, p. 1).

Design science origin

One of the earliest and most influential works is the *sciences of the artificial* (design science) by Simon (1996 - first edition published in 1969), which addresses its roots in engineering and its differentiation from other *exploratory* (*traditional*) *sciences*[30]. Since then there have been numerous contributions discussing the nature and characteristics of design science approaches, in which especially the work of Hevner et al. (2004) has been instrumental in shaping the concept of design science by providing a framework and guidelines for systematic application, primarily targeting information systems where it has received mainstream recognition (Gregor & Hevner, 2013, p. 338). However, design science is not only intended for information systems, but is also intensively used in other areas such as computer science, engineering, education, and health care disciplines (Gregor & Hevner, 2013, p. 339; Vaishnavi & Kuechler, 2015, p. 13). On Hevner´s basis, the research paradigm was further systemized and advanced by Gill and Hevner (2013) who introduced a *fitness utility model* and Gregor and Hevner (2013) who

[30] Johannesson and Perjons (2014, p. 15); Hevner, March, Park, and Ram (2004, p. 76); Gregor and Hevner (2013, p. 338); Vaishnavi and Kuechler (2015, p. 10); Dresch, Lacerda, and Antunes (2015, p. 50)

proposed a framework for classifying design science *contributions*. These two additions are discussed in the following with the basic concepts of design science and the procedure of its application.

Design as research method

The decisive difference between *design science research* and the conventional, often routine design of artefacts is the new field of application in which no solution for certain problems exists, the production of new knowledge in this respect (Vaishnavi & Kuechler, 2015, p. 14), and the relevance of the topic (Gregor & Hevner, 2013, p. 351). Dresch et al. (2015, p. 56) divide the goals of design science research into two aspects:

- The creation of *knowledge* and not only its application.
- The creation of *solutions* to real problems.

In addition, Gregor and Hevner (2013) distinguish four different types of design science contributions, which differ in the maturity of the application domain and the created solution, as shown in Figure 3-1.

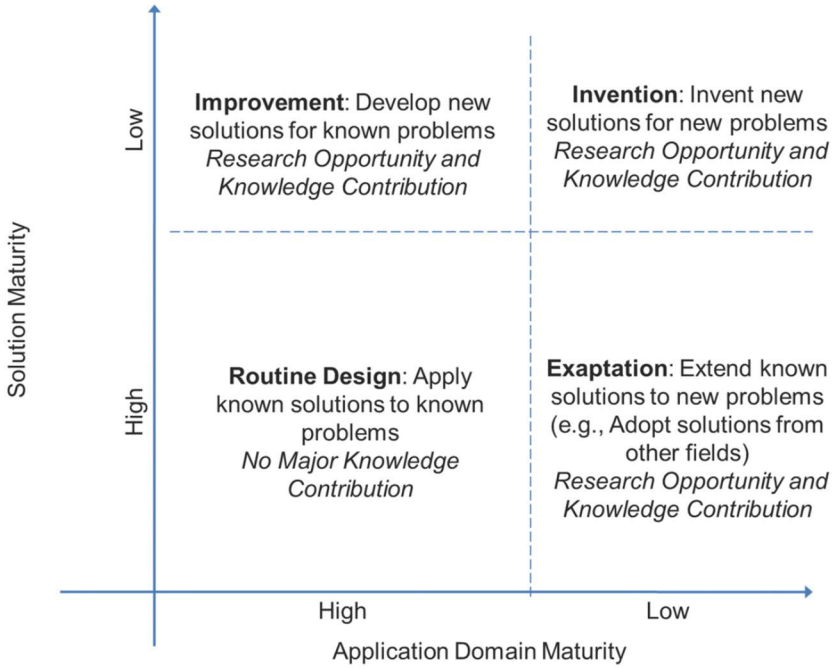

Figure 3-1: Design science research contribution framework (Gregor & Hevner, 2013, p. 345)

Inventions represent the greatest and rarest contribution of design science research as they provide a radical breakthrough and thereby enable new practices and foundations for future research (Gregor & Hevner, 2013, p. 345).

Design science research contributions

Improvements create better solutions in form of more efficient, effective, or usable artefacts in the context of known applications, where current solutions do either not exist or are suboptimal. The 2ndS SDK introduced in this work is classified as such an improvement, because it does not provide a completely new solution, but reduces the development effort of second screen applications and thereby improves this situation.

Exaptation is the adaptation of known solutions to new areas of application and must overcome challenges that were not present in the previous domain.

Routine design usually does not contribute to research because existing knowledge is applied to known problem areas and research methods are rarely needed to solve these issues. In some cases, however, new discoveries can be made in this process, which in turn shifts the contribution to one of the other quadrants (Gregor & Hevner, 2013, p. 347).

Design science research operationalization

In order to provide one of these contributions, several authors formalized methods for the operationalization of design science, of which Dresch et al. (2015, p. 91) have analyzed thirteen with the conclusion that these approaches consist of the same core elements. In all evaluated approaches, the first step of design science research is the concrete *definition of the problem* (100%), followed by a *suggestion for a possible solution* (92%), identifying specific features and requirements of the artefact. The next essential step in all approaches is the actual *development* (100%), usually followed by an *evaluation* (85%) with regard to the relevance of the developed solution and the fulfilment of the raised requirements. Less frequently named steps, as a *literature review* (23%), the *decision about the best solution* (30%), the *reflection and learning* (15%), and the *communication* of the results (15%), as these are often considered as subcategories in the other approaches, and not as separated steps. Essentially, it can be concluded that all surveyed design science approaches are fundamentally similar, in particular in regard to the four mentioned core elements.

Inclusion of research methods and knowledge base

In addition to these core activities, Johannesson and Perjons (2014, p. 77) note that rigorous *research methods* must be applied to ensure the reliability of the results within the application of design science framework. Furthermore, it is necessary to relate both the individual activities and their results to an existing *knowledge base* in order to obtain original and well-founded findings (Johannesson & Perjons, 2014, p. 79).

Applied design science research methodology

These four core activities of design science research are also main components of the methodology proposed by Vaishnavi and Kuechler (2015), who added a final fifth step: *conclusion*. This process model is shown in Figure 3-2 and serves as basis for the design science research approach carried out in this work.

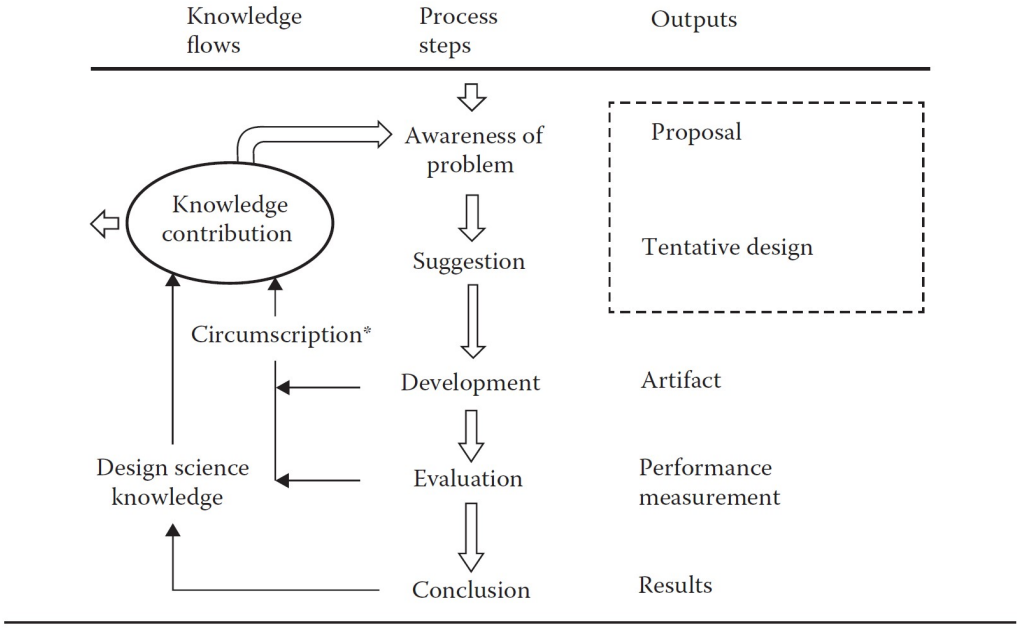

Figure 3-2: Design science research process model (Vaishnavi & Kuechler, 2015, p. 15).

Structure of the development process of the 2ndS SDK

This approach is used to systemize the development of the 2ndS SDK, an artefact that addresses the high effort in the development of second screen applications. The next chapter covers this development and is structured according to the individual activities of the process model for design science by Vaishnavi and Kuechler (2015), where the aims and steps of the single activities are introduced and directly applied.

3.3 Summary Design Approach 2ndS SDK

Summary cross platform development

The development of the 2ndS SDK comprises several areas of research, firstly *second screening*, which is the main theme of this dissertation and was illuminated comprehensively in Chapter 2. In addition, *cross-platform* software development states a central topic, which is was assessed by the related literature as general issue of software development and gains relevance by the increasing fragmentation of platform landscapes in all possible software domains. This heterogeneity causes an increased development effort, which is addressed by cross-platform approaches, e.g. the deployment of software on multiple platforms with the same code basis. However, all approaches so far are considered to have drawbacks compared to native solutions, which leaves the underlying problem of heterogeneous platform landscapes und redundant development unsolved.

Summary design science research

In addition to a brief overview of cross-platform development, the background of *design science research* was discussed in this chapter. *Design science research* is understood as the study and creation of artefacts as they are developed and used with the goal of solving practical problems of general interest (Johannesson & Perjons, 2014, p. 1). There is a long history with many facets that are only briefly summarized in this context, but the resulting approaches systemizing this procedure show a high degree of similarity and can be well applied. The next chapter, the development of the 2ndS SDK, is structured according to the procedure used in this work by Vaishnavi and Kuechler (2015), which includes four identified core activities of design science research and an additional conclusion.

4 Multi-Platform Second Screen SDK

On the basis of the acquired understanding regarding the theoretical background of the areas *second screening*, *cross-platform development*, and *design science research* the multi-platform second screen SDK (2ndS SDK) was created. This process consisted of five core activities of the design science research process model by Vaishnavi and Kuechler (2015), according to which this chapter is structured: the awareness of the problem (cf. Chapter 4.1), a suggestion for the design solution (cf. Chapter 4.2), the actual development (cf. Chapter 4.3), an evaluation (cf. Chapter 4.4), and finally a conclusion (cf. Chapter 4.5)

4.1 Awareness of the Double Multi-Platform Problem

Problem awareness in design science research

The first step towards solving a practical problem in a design science approach is the analysis by a *precise description*, the justification of its *importance*, and ideally the investigation of the underlying *cause* (Johannesson & Perjons, 2014, p. 91), which are discussed in the following. In order to capture the current situation of the second screen development as precise as possible, an actual analysis of the currently available solutions was carried out, which is described in Chapter 4.1.2. Goal of this activity, apart from the insights of the underlying problem, is a proposal on how to address it, which is further elaborated in the second step (Vaishnavi & Kuechler, 2015, p. 16).

4.1.1 Description of the Double Multi-Platform Problem

Description of the double multi-platform problem

The basis of *directly communicating second screen applications* (cf. Chapter 2.3.2) is an established connection between both application parts to enable a direct communication. Since several platforms are available on *the smart TV* side (*fragmentation*), this connection must be established repeatedly from the second screen application to the different first screen platforms available, which causes an increased development effort and the associated typical problems (cf. Chapter 3.1). However, since a second important platform is also available on the *mobile* side, the connections to the various first screen platforms must also be established from this second mobile platform, which doubles the number of redundant development steps. The availability of multiple platforms and the associated problems in

development and maintenance in one domain (cf. Chapter 3.1) can be seen as a *multi-platform problem*. This problem is aggravated in the development of second screen applications by the availability of a second platform domain, as described above, which causes a *double multi-platform problem*. Thereby the development effort is increased on the one hand by the redundant development of the actual applications on the respective sides, and on the other by the repeated connection of the individual parts to create a satisfying second screen experience, as shown in Figure 4-1.

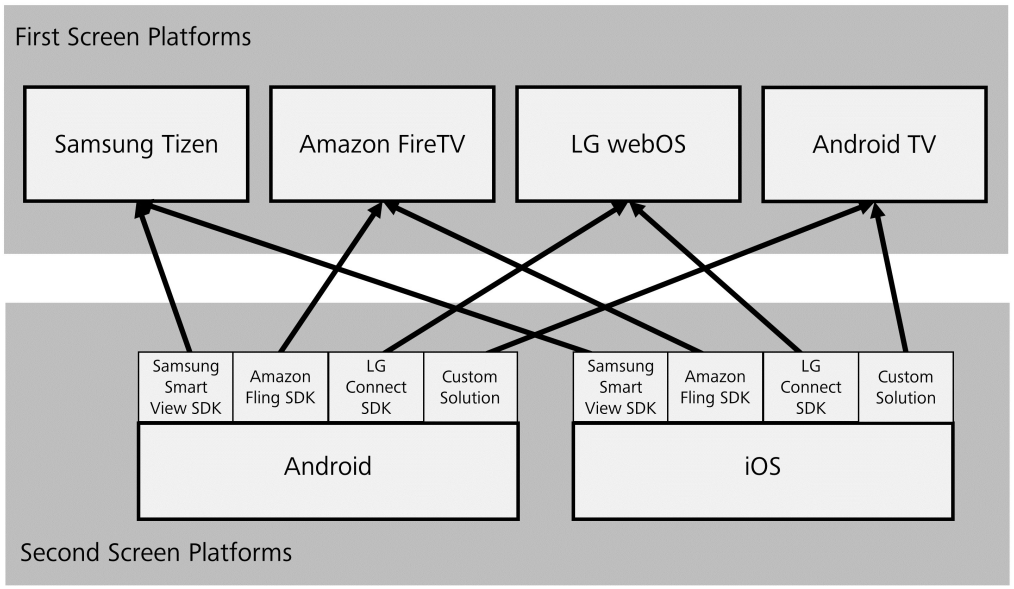

Figure 4-1: Schematic representation of the double multi-platform problem.

Dependency on manufacturer SDKs

This repeated connection process consists of the integration of SDKs from different manufacturers (for example *Samsung Smart View SDK*, *Amazon Fling SDK*, or *LG Connect SDK*), which already represents a high effort. However, if such an SDK is not available for a platform, as with *Android TV*, the developers must either create a custom solution, which drastically increases the implementation effort, or cannot support this platform. An analysis of these SKDs is given in the next section (cf. Chapter 4.1.2) to provide an overview on the current situation in the development of second screen applications.

Importance of overcoming the double multi-platform problem

The relevance of the problem described here arises from the high distribution of second screen *activity* and the potential of (directly communicating) second screen *applications*, as described in detail in the Chapter 2. The development effort

for these applications is currently very high due to the fragmented platform landscapes, which is also a possible reason why this kind of applications have not yet reached their full potential. How a solution to this problem can look like and which requirements it has to meet to address this double multi-platform problem is described in the next chapter, after an analysis of currently available solutions.

4.1.2 Actual Analysis of Current Second Screen Development

Goals of actual analysis

In order to correctly capture the current situation in the development of second screen applications, an *actual analysis* was conducted that includes all relevant smart TV platforms. The goal of this analysis is to provide a comprehensive overview of the solutions currently available to create a connection between first and second screens and a basis for the requirements of the proposed SDK.

Dependence on several manufacturer SDKs

There are currently a number of solutions available to establish a connection between a first and second screen. These solutions are typically provided by the manufacturer of the first screen devices and are available for the most distributed mobile platforms, e.g. *Android* and *iOS*. Most SDKs differ in functionality, maturity, and coding paradigms, but most importantly, all SDKs offered by first screen manufacturers support a very limited number of targeted first screen devices, typically only their own platform. This means that for each supported first screen platform a separate SDK has to be included, which increases the development effort of second screen application as described in Chapter 4.1, the *double multi-platform problem*.

The four SDKs included in the analysis, *Amazon Fling SDK, Google Cast SDK, LG Connect SDK, Samsung Smart View SDK*, and the *DIAL protocol*, which enables second screen devices to find and launch applications on first screens, are presented in the following.

4.1.2.1 Samsung Smart View SDK

General functionality

The *Samsung Smart View SDK* is able to extend *Android*, *iOS*, and *JavaScript* applications to detect and launch compatible receiver devices and communicate with them, after a connection has been established. It also supports additional features such as remotely installing the first screen application, waking the first screen

device from standby with a mobile device (WoW), or device detection via Bluetooth, but only supports *Samsung Tizen* devices from 2014 on. The complete connection process is divided into three phases, which also represent the main functionalities: *discover*, *launch*, and *communicate*.

Sender applications

The sender (second screen) applications must integrate the SDK as a module library to access its functionality. To start or install the TV application, the mobile application must know the *AppID* of the TV application and both applications parts must use the same *channelId* to communicate, which is freely configurable. The *AppID* can be freely selected during development, but must later be changed to an assigned ID from the *Samsung App Store*.

Receiver applications

The receiver (first screen) applications are web applications consisting of *HTML*, *JavaScript* and *CSS*, and must be developed with the *Tizen TV IDE*, because installation and debugging is only available with this IDE. Communication requires that the sender and receiver applications use the same *channel* and *event IDs*, enabling reliable bi-directional communication based on *WebSockets*.

Conclusion Smart View SDK

The Samsung Smart View SDK is the best-elaborated SDK tested in this analysis. It not only offers a wide variety of reliable functionalities, but also good documentation with working examples and is maintained regularly.

4.1.2.2 *LG Connect SDK*

General functionality

LG's Connect SDK pursues a similar goal as the 2ndS SDK developed here: a mobile SDK that supports multiple TV platforms and provides discovery, launching and communication capabilities for first and second screens. In addition to these basic features, *LG webOS* devices have a number of additional features available, such as retrieving a list of installed applications, remotely installing applications, displaying toast alerts, and keyboard inputs with the second screen. The Connect SDK is available for *iOS*, *Android* and *Cordova*.

Sender applications

The setup of the Connect SDK for the *sender* device (second screen) can be done automatically by enabling a dependency in the mobile application project, or by manually integrating the source files, which is associated with a certain complexity. In addition, there are multiple versions of the SDK with different numbers of supported TV platforms available, which adds to the complexity of

the integration process. The launch of webOS applications requires either a specified *webOS application ID* or the *DIAL ID* (cf. Chapter 4.1.2.2) of the application.

Receiver applications

WebOS receiver applications use the web technologies *HTML*, *JavaScript*, and *CSS* and require an online registered *application ID* to be launched from a mobile device. Receiver applications integrated the *Connect SDK* by two *JavaScript* scripts that enable the functionalities of media playback and control, as well as bidirectional communication with the sender application.

Conclusion LG Connect SDK

The Connect SDK is a good approach to facilitate the development of second screen applications, but the current version has serious problems, especially in terms of actuality. The latest version at the time of the analysis was updated in September 2015, resulting in incompatibility with newer *Android* versions. The core functions of the SDK are working, but its execution leads to several exceptions und instabilities. An extension of the *Connect SDK* for the future integration of additional Smart TV platforms to create a solution for all major TV platforms seems however unlikely. During the course of the project, the official Connect SDK website has been and currently (17.03.2019) is offline for a longer period of time, making SDK documentation not accessible to developers and indicating a low interest of future support of the *Connect SDK*. These factors contribute to the conclusion that the Connect SDK is an unsuitable component for a reliable software project, and should not be integrated if not necessary.

4.1.2.3 *Google Cast SDK*

Sender applications

The *Google Cast SDK* allows an extension of *Android*, *iOS,* and *Chrome* applications to transfer video and audio content to supported first screen platforms (*Cast Applications*) and control features on mobile devices. It is important to note that although the SDK distinguishes between sender and receiver applications, the first screen application cannot work without its counterpart, which acts as a remote control. Sender applications provide three basic functionalities: *discovering*, *launching*, and *connecting* receiver applications on the local network by establishing a communication channel.

Receiver applications

Receiver applications are implemented in *HTML*, *JavaScript*, and *CSS* and are retrieved from a hosted URL each time they are launched. Because these applications are not installed on the device, no data can be stored on them, which limits the functionality of these cast applications. Receiver apps must be registered with the *Google Cast SDK Developer Console*, where an *app ID* is generated for the launch with a sender app. Each Android TV and other supported devices, as Fire TVs, have an integrated *cast receiver* that supports cast applications.

Difference Cast and Android TV applications

It is important to note the difference between these *Cast* and *Android TV* applications, which are very similar to mobile Android applications. Table 4-1 provides an overview on the most important differences between the two named applications types. The Google Cast SDK, however, only supports *Cast* applications, which is why there is currently no existing solution to support *Android TV* applications as a first screen platform.

	Google Cast Applications	Android TV Applications
Standalone Application	No	Yes
Programming Language	HTML, JavaScript & CSS	Java
Installable on First Screen	No	Yes
Compatible with *Google Cast SDK*	Yes	No

Table 4-1: Overview on differences between Google *Cast* and *Android TV* applications.

4.1.2.4 *Amazon Fling SDK*

General functionality

The *Amazon Fling SDK* enables *Android*, *iOS* and *Fire OS* applications to discover, connect, and transfer media and web content to *Amazon Fire TV* devices over the local network. The *Fling SDK* is also compatible with *Google Cast* applications (cf. Chapter 4.1.2.3), because *Fire TV* applications are based on *Android TV*.

Sender application

In order to use the functionalities of the *Fling SDK*, the mobile application needs to integrate two libraries as modules (*Fling* & *Whisperplay*). This allows the mobile application to detect *Fire TVs* in the local network, start the corresponding first screen application, or install it if needed. Once the first and second screens are connected, the mobile device can transfer media content such as video, audio, and pictures. Furthermore, an exchange of meta information and the control of the connected contents is possible with the *Fling SDK*, but no customizable bi-directional communication.

Receiver application

Fire TV receiver applications need to include the same libraries as their mobile counterparts (*Fling* & *Whisperplay*). In addition, the TV application needs to provide a unique service identifier (SID) specified in a separate file (*whipserplay.xml*), in order to launch it remotely.

Conclusion Fling SDK

The Fling SDK provides basic functions to create a second screen interaction for Fire TV devices, but is limited by the restricted communication, which makes it only partially useful.

4.1.2.5 *DIAL Protocol*

DIAL overview

The *DIAL protocol* enables second screen devices to *discover* and *launch* applications on the first screen in a local network. The protocol developed by *Netflix* and *YouTube* owes its name to this functionality (*Discover* & *Launch*) and does not include a solution for communication between the first and second screen. A large number of first screen devices, such as *Android TV* or *webOS*, support this protocol and current solutions such as the *LG Connect SDK* (cf. Chapter 4.1.2.2) are based this technology.

Sender application

In contrast to the SDKs of the manufacturers, the functionality of the DIAL protocol has to be implemented by developers with the help of provided specifications, which represents a comparatively high effort. The process consists of two basic components: *DIAL Service Discovery* (*discover*) and *DIAL Rest Service (launch)*. The first step enables second screen devices to discover compatible first screen devices in the local network with an *M-Search SSDP* request (Simple Service Discovery Protocol), a protocol based on *UPnP*, and the second to query and launch

found devices using *HTTP*. The specified *application name* of the first screen application is the only external resource needed to start applications with *DIAL*, everything else can be implemented directly. When launching the first screen application it is also possible to pass parameters from the mobile device, which is used in the 2ndS SDK to establish a communication, which is not included in the DIAL Protocol.

Receiver application

Receiver applications must provide an *application name* under which they are addressed by the mobile part, which is entered in a public register and is therefore accessible to all developers. However, this registration of the application name causes problems in the implementation of the dial protocol. Despite several attempts, it was not possible to launch self-registered applications with the DIAL protocol. The examples provided, *YouTube* and *Netflix*, worked as intended, but any other registered application did not. This behavior has also been reported by the developer community[31] and has not yet been resolved. The only exceptions to this behavior are *Fire TV* applications, where the *application name* does not have to be registered online, but is specified locally, and *Sony Android TV*, where a description on how to solve this problem is provided. Because of these limitations, the DIAL protocol can only be used on these platforms in 2ndS SDK. The cause of this problem seems to be the implementation of the DIAL server on the first screen devices, which is not accessible for developers. The *DIAL Server* and the *DIAL Registry* do not seem to synchronize their lists of known applications, which makes it impossible to create custom, launchable applications, as displayed in Figure 4-2.

[31] https://stackoverflow.com/questions/38488965/dial-protocol-for-launching-android-application http://stackoverflow.com/questions/38982180/app-name-to-use-for-dial-on-sony-tv-with-android-o-s https://stackoverflow.com/questions/21434324/using-dial-protocol-in-android-application

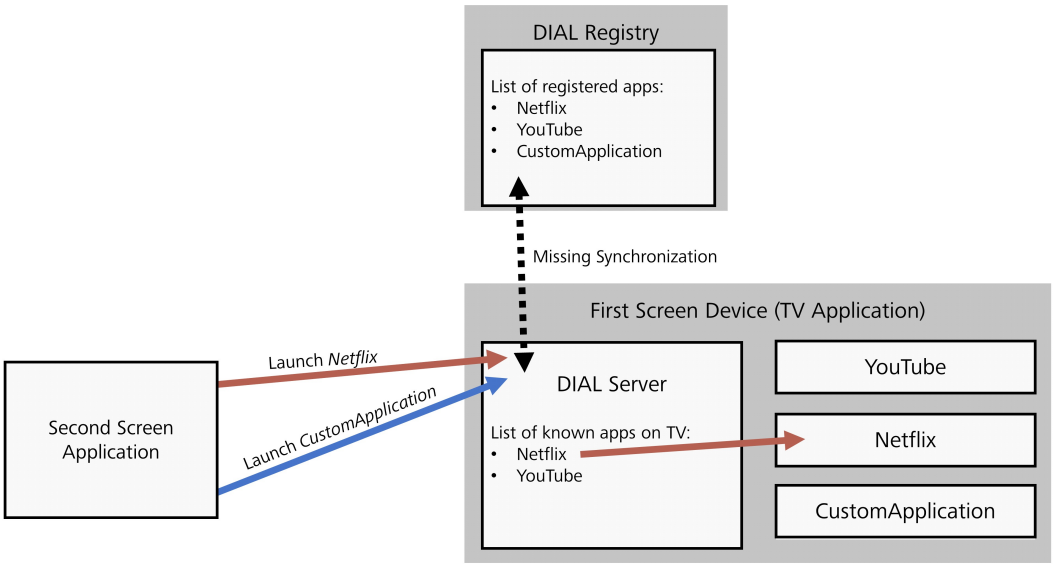

Figure 4-2: Schematic representation of the missing synchronization between *DIAL Server* and *DIAL Registry*, which prevents the launch of custom applications.

Receiver application

The DIAL Protocol would provide a satisfying solution for *discovering* and *launching* second screen applications if it worked as intended. Apart from the problem with the launch of the applications on most platforms, the protocol must be implemented by the developers, unlike SDKs, which increases the development effort. Furthermore, it does not include a method of communication, which has to be implemented additionally. Because of these problems, the use of the protocol is limited, but is still provides an addition to the 2ndS SDK. The next section provides a short overview on the evaluated solutions in second screen development and their functionalities.

4.1.2.6 *Results Actual Analysis*

The analysis of existing solutions for establishing a connection between first and second screens showed that all approaches are associated with essential problems, such as the limitation to one first screen platform, missing communication, or faultiness. Table 4-2 provides an overview on the different functionalities of the evaluated solutions.

	Samsung Smart View SDK	Amazon Fling SDK	LG Connect SDK	Google Cast SDK	DIAL Protocol
Discover	Yes	Yes	Yes	Yes	Yes
Launch	Yes	Yes	Yes	Yes	Yes
Communicate	Yes	No	Yes	Yes	No
Fully Functional	Yes	No	No	Yes	No
Single Target Platform	Yes	Yes	No	Yes	No
Install	Yes	Yes	Yes	No	No
WoW	Yes	No	No	No	No
List installed Apps	No	No	Yes	No	No
Mouse Controls	No	No	Yes	No	No
Power off device	No	No	Yes	No	No

Table 4-2: Overview of current solutions functionalities.

The analysis also provided insights for the design of the 2ndS SDK, such as the distinction between three basic steps for establishing a connection: *discovery*, *launch*, and *communication*, or the support of *Android* and *iOS* with separate single module libraries without compiling. The exact outlined solution with its requirements is described in the next chapter.

4.2 Suggestion for the Design Solution

Second step in the design science research process

In the design science research process, once the underlying problem has been described, a suggestion in form of an artefact is proposed to address it. The results from this second activity is a *tentative design*, which is continuously further developed in the course of the project (Vaishnavi & Kuechler, 2015, p. 15). The outlined solution is to be described as detailed as possible and ideally, requirements for the later evaluation are raised. The solution to address the double multi-platform problem described above is the *2ndS SDK*, which is introduced with the raised functional and non-functional requirements in this chapter.

4.2.1 Outlining of the 2ndS SDK

The 2ndS SDK

The aim of this work is to provide a solution to address the previously described *double multi-platform problem* that arises in the development of second screen applications (cf. Chapter 4.1.1). The proposed solution consists of a middleware SDK, the *2ndS SDK*, which is able to address multiple first screen platforms and is available for the most distributed mobile platforms, *Android* and *iOS*. Thus, it reduces time and workload for development and maintenance of second screen applications. The 2ndS SDK provides a unified approach to *discover*, *launch*, and *communicate* with multiple first screen platforms at once, eliminating the need to repeatedly create connections with different SDKs. It should be noted that this does not eliminate the problems of redundant software development for first and second screen applications itself, but rather for the complex connection process between them. The aim is also not to create a completely new solution (e.g. a new protocol or similar), but to build on existing approaches in order to avoid the creation of isolated solutions, which are less likely to be used by developers or even remain non-functional without the support of the platform distributers. The chosen approach of the 2ndS SDK to address the double multi-platform problem in the development of second screen applications is shown schematically in Figure 4-3.

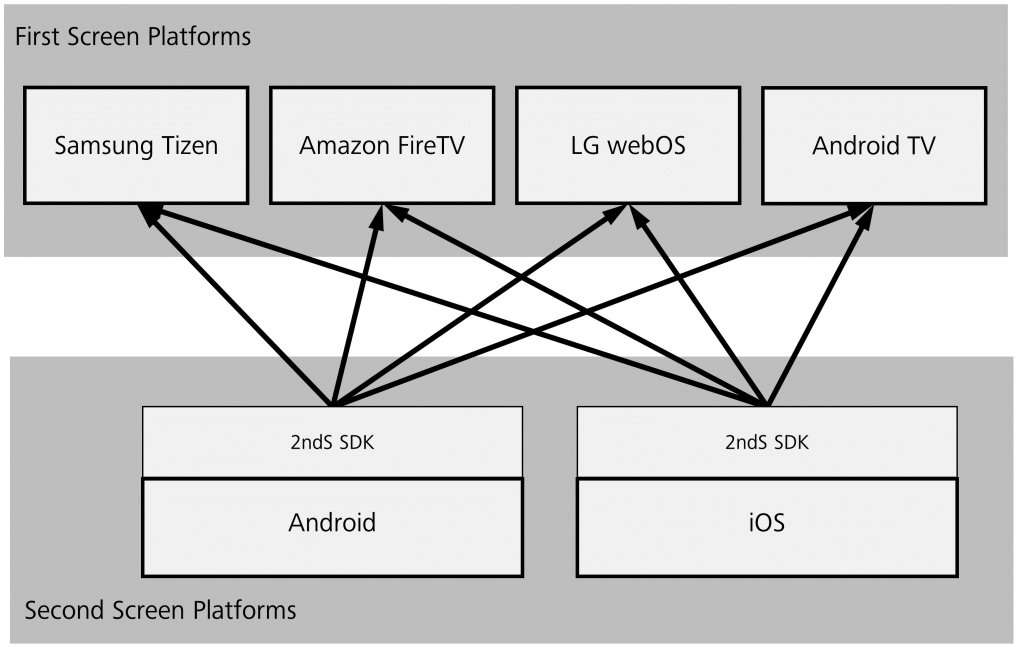

Figure 4-3: Approach of the 2ndS SDK to address the double multi-platform problem in the development of second screen applications.

In the analysis of existing solutions (cf. Chapter 4.1.2), the basic functional scope of the SDK was determined in order to enable a satisfactory interaction between the two application parts, of which the results are displayed in Table 4-3.

Function	Description
Discover	Automatically find and display compatible devices in the local network
Launch	Launch first screen application from the second screen without registration or other complex steps
Communicate	Open bidirectional text-based communication between all connected devices
Register Disconnect	Dectection of connection losses on the second screen
Install (Optional)	Open the page for installing the first screen application in the respective store

Table 4-3: Overview of core functionalities of the 2ndS SDK.

2ndS SDK core functionalities

The core functions are the *discovery*, *launching*, and bi-directional *communicating* with different first screen platforms, available for *Android* and *iOS* devices. In *discovery*, the reliable detection of all available devices is important and the possibility to retrieve their names so that users can select the correct device. After that, an application should be *launchable* directly from the mobile device without any further steps. The third core functionality is a stable bidirectional *communication* between all connected devices, because the exchange of information between the devices is a basic requirement for a satisfying interaction. In addition, mobile devices must be able to detect *connection losses* for error handling and to restore functionality. The remote install of first screen applications eases the use of second screen applications, but is no prerequisite for a satisfying experience. In addition to this feature set, a number of requirements were raised to ensure the quality of the 2ndS SDK, which are presented in the next section.

4.2.2 Raised Software Requirements

Raising of the requirements

Requirements are properties that are deemed desirable in practice and are used for guiding the design and development of the artefact (Johannesson & Perjons, 2014, p. 103). The requirements of the outlined SDK were collected, prioritized, and specified based on the analysis of existing solutions in cooperation with *MEKmedia*[32]. The aim was to identify concrete requirements for an artefact to address the *double multi-platform problem* and to create quality standard beyond the scope of a prototype.

Supplement from literature

These requirements have been supplemented with appropriate literature, especially with regard to the cross-platform character of the 2ndS SDK. The most important factors were identified to be *performance* (efficient use of device resources & responsiveness), *reliability* (robustness, connectivity, stability), *installability* (Wasserman, 2010, p. 399), *scalability*, access to *device features*, and the use of existing *development environments* (Latif et al., 2016, p. 4).

[32] Matthias Moritz, Roman Rückel, and Matthias Löffelmann.

In the following, *functional* and *non-functional* requirements are distinguished, which describe the functional scope of the system on the one hand and the associated constraints on the other (Sommerville, 2016, p. 105).

4.2.2.1 *Functional Requirements of the 2ndS SDK*

The functional requirements are presented in Table 4-4 for better overview. The requirements are written in natural language for better understanding, and are grouped into *connection*, *communication*, *architecture* and *others*:

ID	Description	Priority
Connection		
F01 Find	The SDK must be able to find all supported devices in the current network and retrieve their names	***
F02 Launch	The corresponding first screen application must be launchable from the second screen	**
F03 Connect	The SDK must be able to establish a connection between the devices	***
F04 Connection loss	The SDK should be able to detect connection losses from the second screen	**
Communication		
F05 Communication Standardization	The SDK should provide a possibility to create an standardized communication between the application parts	**
F06 Open Communication	The SDK must provide an open channel (e.g. strings) for a bi-directional communication	***
F07 Multi Communication	The SDK should be able to establish a communication between multiple devices and device types	*

ID	Description	Priority
Architecture		
F08 Integrability	The SDK should be integrable in the most common developer tools for each mobile platform	***
F09 Individuality	The SDK should be able to address each first screen platform individually	**
F10 Expandability	The SDK should be expandable for further TV platforms	**
Other		
F11 Multi-Platform Development	The SDK must be able to address multiple first screen platforms at once	***
F12 API	The SDK must provide one unified interface for all supported first screen platforms	***
F13 Debugging	The SDK should provide exceptions to provide help finding errors	*
F13 API Documentation	The SDK must provide an API documentation to facilitate the usage of the SDK	***
F14 Technical Documentation	The SDK must provide a technical documentation for maintaining and expanding the SDK	**

Table 4-4: Specified and prioritized functional requirements of the 2ndS SDK.

4.2.2.2 *Non-Functional Requirements of the 2ndS SDK*

The distinction between the different types of requirements is often not as clear as the definitions initially suggest (Sommerville, 2016, p. 105), but ultimately serves the purpose of keeping the overview. Especially with the non-functional requirements often different groupings are suggested (Johannesson & Perjons,

2014, p. 103), but here regular *non-functional requirements* (cf. Table 4-5) and *software quality attributes* (cf. Table 4-6) are distinguished and presented in the following:

ID	Description	Priority
Performance		
NF01 Delay	The SDK should not compromise the performance of the integrated application	***
NF02 Internal Delay	The communication between the first and second screen device should not be delayed by the SDK itself. External factors, e.g. delays by external servers etc., are out of the scope of the SDK	**
NF03 Transaction	95% of the transactions shall be processed in less than one second	*
Market Coverage		
NF04 Mobile Support	The SDK should be available for the most distributed mobile platforms (95%)	***
NF05 First Screen Support	The SDK should be able to address to most distributed first screen platforms (90%)	***

Table 4-5: Specified and prioritized non-functional requirements of the 2ndS SDK.

Software quality attributes are distinguished as *reliability*, *maintainability* and *usability* as presented in the following:

ID	Description	Priority
Reliability		
SQ01 Stable	Unknown errors should occur less than 5% of operation time within the SDK.	**
SQ02 Error Safe	The SDK should remain functional at 95% of the errors.	**
SQ03 Stable Connection	The SDK should be able to establish a stable connection between first & second screen devices	***
SQ04 Reliable Connection	The SDK should provide a reliable form of communication between to connected devices	**
Maintainability		
SQ05 Modularity	The SDK should provide a clear structure and separation of application logic, so that future changes can be applied as easy as possible	***
SQ06 Comments	Comments should be used within the code to ease the understanding of the application logic	*
SQ07 Error Handling	The SDK should be able to report the about location of problems that occur within the SDK	**
Usability		
SQ08 No Registration	No registration or further input should be necessary for the discovery process	***
SQ09 Automatic Connection	The connection process should work without further configuration as the exchange of as IP addresses, security codes, or registration	***

ID	Description	Priority
SQ10 Unified Coding Paradigm	The API should be reduced to one common paradigm for the discovery, launch, and communication process for all different first screen platforms	*

Table 4-6: Specified and prioritized software quality attributes of the 2ndS SDK.

4.3 Development of the 2ndS SDK

Third step in design science research

The third activity in the design science research process is the actual development of the artefact to address the identified problem, on basis of the outlined solution to fulfill the requirements of the previous activity (Johannesson & Perjons, 2014, p. 117). The sub-activities in this step differ depending on what kind of artifact is created and are difficult to generalize because most projects are very individual. Mostly, however, the novelty thereby arises primarily in the design and not in the implementation (Vaishnavi & Kuechler, 2015, p. 16), which is why the 2ndS SDK is discussed more on a conceptual level, than on code basis.

4.3.1 Architecture of the 2ndS SDK

Concept derived from literature

The most important factor identified in the literature to address cross-platform problems a *layered architecture* (Pausch, Conway, & Deline, 1992, p. 324). By adding *abstraction layers* in the form of OS-decoupled code (Brzozowski et al., 2011, p. 9), a unified and simplified interface for the developers can be created that abstracts the underlying complex functions (Martinez-Pabon, Caicedo-Guerrero, Ibarra-Samboni, Ramirez-Gonzalez, & Hernandez-Leo, 2015, p. 4). In addition, the native code of the individual platforms can be used in the lower layers to achieve a high performance (Brzozowski et al., 2011, p. 295). The *loose coupling* of the different modules also enables increased *stability*, because abstracted layers are reused and already tested (Brzozowski et al., 2011, p. 7), and *extensibility*, because new native layers can be added more easily if required. Previous ap-

proaches with similar architectures have shown, that this approach can be successful without significant penalty in performance (Brzozowski et al., 2011, p. 7), which is a prioritized requirement. The designed approach of the 2ndS SDK is represented schematically in Figure 4-4 and described in more detail in the next chapter after a brief summary of the development process.

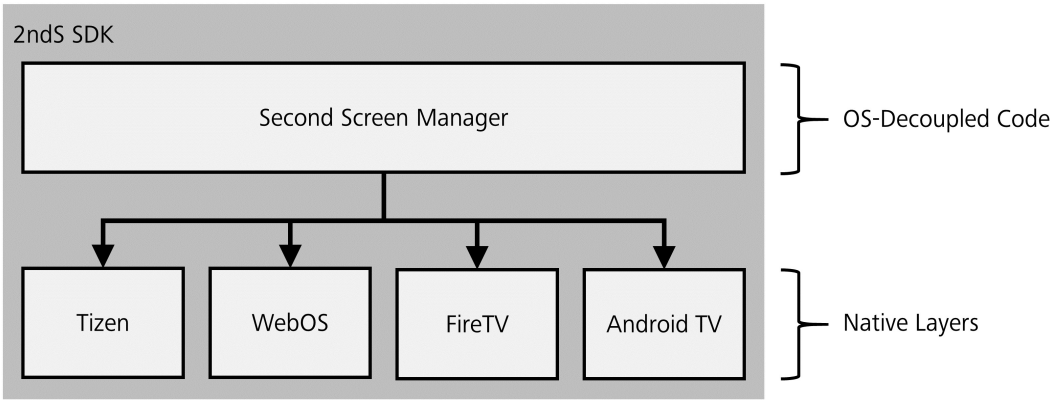

Figure 4-4: Simplified schematic representation of the layered architecture of the 2ndS SDK

General development procedure

The development of the 2ndS SDK consisted of multiple iterations. First, a rough concept of the architecture was designed with a single layer, *Samsung Tizen*, as this was assessed as the best existing solution in the previous analysis (cf. Chapter 4.1.2). Subsequently, step-by-step solutions for the other layers were developed and integrated into the existing architecture. The SDK was developed by creating functional prototypes to ensure its functionality at all times, which are described in detail in Chapter 5. In the first step, a basic media library application for *Android* and *Tizen* was developed (cf. Chapter 5.1), and in the second step, an application with a higher degree of maturity (cf. Chapter 5.2), in which the additional layers were added. In addition to ensuring functionality, this also had the advantage that different concepts for second screen interaction could already be designed and tested during the development phase. After all layers were functionally implemented on Android, *MEKmedia*[33] revised the SDK and transferred it to *iOS* in an exact image of the functionality. The most important aspects of the final

[33] Android refactoring by Roman Rückerl and iOS development by Vladica Pesic

version of the 2ndS SDK are presented in the following, a complete overview can be found in Appendix A.

Structure of the native layers

Within the smart TV layers, several *interfaces* are available that provide abstract methods to enable a uniform structure between the layers and better extensibility. The *ISecondScreenService* and the *ISecondScreenClient* are to be mentioned in this context. The first describes the methods required by the abstraction layer (*SecondScreenManager*) for the consistency of the functional scope on all platforms. (Choudhary, 2014, p. 643). The *ISecondScreenClient* provides the callbacks for asynchronous communication between the individual layers and methods for the associated loose coupling (Liu, Yung, & Chung, 2010, p. 88). Currently there are three services available for the connection of the different first screen platforms, the *TizenService*, *WebOsService*, and *DialService*, and one additional layer for communication, the *SignalRClient*, as displayed in Figure 4-5. These layers are utilizing the capabilities of available technologies by wrapping the existing SDKs and protocols in the format required by the 2ndS SDK for seamless deployment.

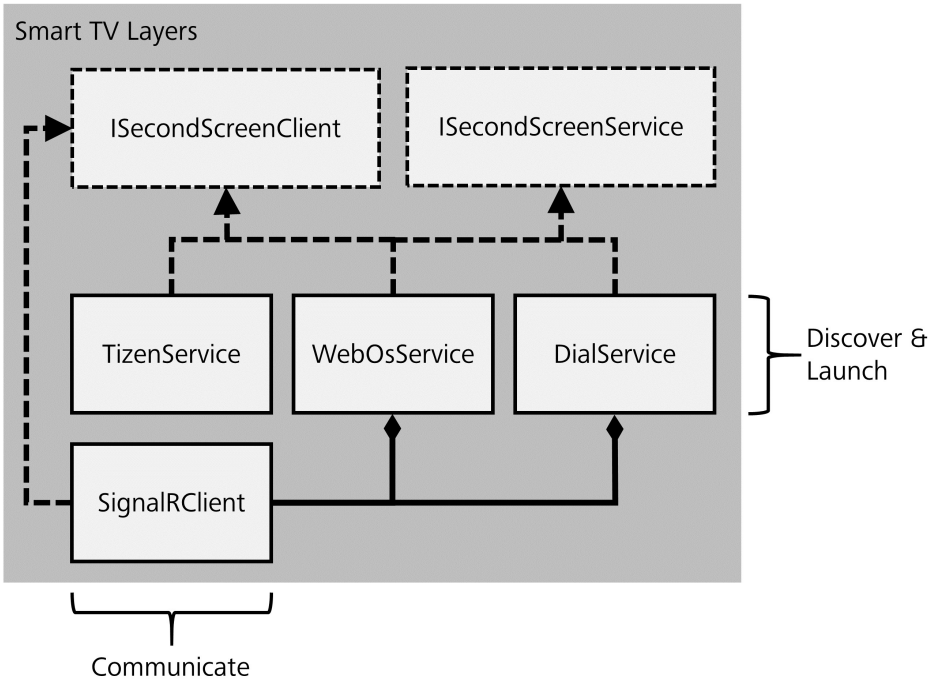

Figure 4-5: Simplified schematic overview of the functionality of the native first screen layers in the 2ndS SDK.

Underlying functionality of the layers

For *Tizen*, the existing *Smartview SDK* could be used with only minor adjustments for the discovery, launch, and communication process, while for the other layers this functionality had to be split. Because the *Connect SDK* is deprecated and therefore not fully functional (cf. Chapter 4.1.2.2), it is only used to discover and connect *WebOS* devices, the communication was moved in a separate layer as with the *DIAL* service, because communication is not possible with the protocol (cf. Chapter 4.1.2.5). Within the *DialService* different platforms are differentiated; *FireTV* is completely functional, but *Android TV* differs from the other available TV manufacturers. Here, only *Sony* devices can be supported, because information about the implementation of the *DIAL server* is available, as described in more detail in the actual analysis (cf. Chapter 4.1.2.5).

Separation of communication layer

The communication with *WebOS* and *DIAL* clients was implemented with the help of *SignalR*[34], a library for real-time communication with *WebSockets*, if available, and other fallback solutions if not. This communication structure enables a wide scaling with several devices on different platforms. The connection of the different first and second screen clients is enabled by the exchange of generated IDs as *launching parameters* when starting the application (cf. Chapter 4.1.2.5). For the detection of connection losses, a mechanism is built into the communication channel that exchanges messages between the connected devices at regular intervals. If these regular interval messages do not register on the second screen part, a corresponding exception is triggered within the 2ndS SDK. These *SecondScreenExceptions* were created throughout the SDK to help solve problems in the program flow for more efficient troubleshooting.

4.3.2 SDK Function Scope

Integration of the 2ndS SDK

The 2ndS SDK was implemented as native plugin for *Android* and *iOS* and can be integrated in Android Projects by adding it as external module library and to iOS as a framework in the form of embedded binaries. This enables the SDK in its

[34] https://docs.microsoft.com/de-de/aspnet/signalr

existing form to also be used for cross-platform approaches such as *Apache Cordova*[35] or *Xamarin*[36].

Initialization of the supported platforms

The only interface to the developer is the *Second Screen Manager* class, which provides functions for *finding*, *launching*, and *communicating* with multiple smart TV platforms. The first step toward this functionality is the *initialization* of the targeted platforms. The individual platforms require different parameters for initialization, because the dependencies of the underlying technologies cannot be resolved completely. For example, all platforms require the ID of the corresponding first screen application, but only *Tizen* an explicit communication channel, because this is a prerequisite of the *Smart View SDK* used here (cf. Chapter 4.1.2.1). Each supported platform has its own initiation function, i.e. *initializeWebOs*, *initializeTizen*, etc., which also increases the flexibility of the 2ndS SDK by providing the ability to address platforms individually. These different initiation functions are the only place in the 2ndS SDK where the developer has to distinguish the different platforms, everything else is handled automatically.

Search and connection process

For the discovery of compatible devices, the local network is searched for all previously initiated platforms and, if successful, a device object is returned that has a unique *ID*, *name*, *manufacturer*, *connection status*, and the capacity of further occasionally needed attributes. This information can be presented to users and then, if desired, start the connection process. After triggering, the 2ndS SDK continues the search for compatible devices until it is stopped with the corresponding function (*stopSearch*) or a connection is established. The automatic connection to found devices is generally considered bad practice and should only be performed under certain circumstances to *known* devices (cf. Chapter 8.3.1). In order to establish a connection, the previously found *device* object must be passed to the corresponding function (*connect(device)*).

Communication

After a successful connection, the SDK enables a text-based communication between all devices (*sendMessage(string)*). In addition, an infrastructure for an

[35] https://cordova.apache.org
[36] https://docs.microsoft.com/de-de/xamarin

event-based communication with *commands* and *events* was created, since this approach was evaluated as the best solution for a loosely coupled communication in dynamic environments in an analysis of previous work (Martinez-Pabon et al., 2015, p. 3). For this the class *SecondScreenCommand* was created, and is based on *JSON* objects in a defined structure for a uniform exchange of information, which are available through the function *executeCommand(command)* in the *Second Screen Manager*. Receiving messages and finding compatible devices in the network is implemented with callback functions in an interface (*ISecondScreenClient*) to allow an asynchronous and flexible exchange between in individual components.

Helper functions

Developers do not need to distinguish the type of platform they interact with in the search, connection, and communication, as the different requirements are handled by the SDK and have the same functionality due to the abstraction layer. In addition to the core functions, the *SecondScreenManager* offers helper functions with which found devices (*getDevices*), the current connection status (*isTVConnected*), and all connected devices (*getCurrentConnectedDevice*) can be retrieved. The complete function scope of the 2ndS SDK provided by the *Second Screen Manager* is given as overview by Table 4-7.

Function	Description
SecondScreenManager	
initialize*Platform*(…)	Initialization of the individual platforms with the parameters required
search()	Searching the lokal network for compatible devices
stopSearch()	Stops the searching the lokal network
connect(device)	Establish a connection with found devices
disconnect()	Disconnect mobile client

Function	Description
sendMessage(string)	Send string message to all connected devices
executeCommand(command)	Send *SecondScreenCommand* to all connected devices
getDevices()	Retrieve list of all found devices
isTVConnected()	Retrieves connection status
getCurrentConnectedDevice()	Retrieve currently connected device

Table 4-7: Function scope of the 2ndS SDK provided by the *SecondScreenManger*

4.4 Evaluation

Evaluation in design science research

In the evaluation phase in design science research (Vaishnavi & Kuechler, 2015, p. 16), the created artifact is assessed in terms of its ability to solve the problem addressed (cf. Chapter 4.1) and the extent to which it fulfills the collected requirements (cf. Chapter 4.2) (Johannesson & Perjons, 2014, p. 137).

Improvement by the 2ndS SDK

With regard to the underlying *double multi-platform problem* in the development of second screen applications (cf. Chapter 4.1), a middleware SDK has been created that provides a unified interface for the most distributed mobile platforms to support multiple first screen platforms. This approach in itself represents a substantial improvement of this situation, since it eliminates several redundant development steps. To what extend the 2ndS SDK is effective for solving the problem is presented in the following.

Evaluation by demonstration

It is difficult to capture some of the criteria in formal evaluations, such as the improvement of the overall situation by the SDK or some of the functional requirements. Therefore, multiple functional prototypes were created to demonstrate the use of the 2ndS SDK, which are presented in the next chapter (cf. Chap-

ter 5). These demonstrations can be seen as a weak form of evaluation; if the artifact addresses the problem in this case, so can it in other cases (Johannesson & Perjons, 2014, p. 133).

In addition to demonstrating the functionality with the prototypes created, which are considered *formative*, a *summative* evaluation of the 2ndS SDK was carried out in order to evaluate the non-functional requirements in particular.

4.4.1 Evaluation Approach

Evaluation objectives

The aim of the evaluation was to examine the requirements that had been raised, because no comparable solution exists. This evaluation examined the basic *functionality* of the SDK, its *performance*, and *reliability*, in particular in relation to the communication between different devices. Performance and reliability are prerequisites for satisfactory interaction and are particularly prone to error in distributed systems. Lag, the delay between input action and output response, plays a central role in this process and is in this context a serious bottleneck of usability (MacKenzie & Ware, 1993, p. 493) and is thus one of the central investigation variables in the evaluation.

To do so, a mobile application for *Android* and three first screen applications for the currently supported layers, *Amazon FireTV*, *LG WebOS*, and *Samsung Tizen* were created. The test procedure was chosen to represent the basic functions of the SDK:

- *discovering* each first screen platforms in the local network,
- *launching* the corresponding application,
- *communicating* by exchanging a series of messages between the two applications parts.

Test procedure

Every 100 milliseconds a message was sent from the mobile side to the connected counterpart and from there directly back to the mobile application. In this message, a timestamp was recorded in each layer of the SDK to estimate the delay and the abstraction penalty in each station (Brzozowski et al., 2011, p. 10). Each message and the corresponding timestamps were stored in a log file for later evaluation. The most reliable approach in this context is measuring the *round time*, the

time between the start and end points of the message, as the timestamps are collected on the same device and the precise synchronization in the millisecond range cannot be guaranteed on different devices. No visualization was carried out on both application parts in order to reduce possible disruptive factors and to obtain the most accurate possible assessment of the communication. The frequency of messages was deliberately chosen to be higher than is likely to occur with regular second screen applications in order to test the existing boundaries. In this way, 36000 messages were collected for each first screen platform to give an assessment of the quality of communication.

Test setting

The test was conducted in a setting as natural as possible, with a *Samsung Galaxy S7* as *Android* test device and as first screen platforms a FireTV (2. Generation), a *LG* (LG 55UJ6519) and *Samsung* TV (UE48JU6050U). The next section presents the results from the evaluation.

4.4.2 Evaluation Results

Round time and estimated single time

The analysis of the collected data has shown that the communication between the first and second screen is reliable and performant, although there are notable differences between the different layers. The basis of the measurement is the *round time* of the individual messages, from the second to the first, and back to the second screen. It is assumed in this evaluation, that the *single* time from the second to the first screen is half of the round time. The *average* round times measured, their *standard deviation*, the *minimum,* and *maximum* values occurring, and the *estimated* single time from second to first screen are shown in Table 4-8. These values are limited to communication only, for the visualization of inputs an additional time has to be considered.

Round Trip Time (n=36000)	FireTV	Samsung Tizen	WebOS
Average (ms)	110.43	16.44	143.92
Std (ms)	163.49	15.30	284.30
Min (ms)	63	10	60
Max (ms)	12329	446	13211
Estimate First Screen Time (ms)	55	8	72

Table 4-8: Average time, standard deviation, minimum, and maximum values with estimated time to first screen of the collected data.

Measurements are within the acceptable range

Nielsen (1993, p. 135) describes *100 milliseconds* as limit for having the feel that the system is *reacting instantaneously*, which is within the scope of all estimated average times of the first screen. Even with the greater scatter of the *FireTV* and *WebOS* layers, most measurements fall below this value, as shown in Figure 4-6. The limit of *1000* milliseconds for an uninterrupted interaction was reached in the test only by single outliners. MacKenzie and Ware (1993, p. 493) also note that even smaller delays of 75 milliseconds are noticeable, but that the error rate only increases after 225 milliseconds. The test results obtained here therefore fall within the acceptable range.

Differences between native layers

The most constant and fastest measurements were recorded on the *Samsung Tizen* layer, which has the ability to communicate directly over the local network and without the need for an internet connection. The other two layers use *SignalR* for communication (cf. Chapter 4.3.1), which works with an external server and is presumably therefore slower, but still within the acceptable range. Probably due to this external dependency, the outliers in these measurements are considerably higher (up to 13 seconds), but nonetheless existing in all measurements. Reasons for this could be, besides the load of the communication server or the internet connection, background activities of the first or second screen.

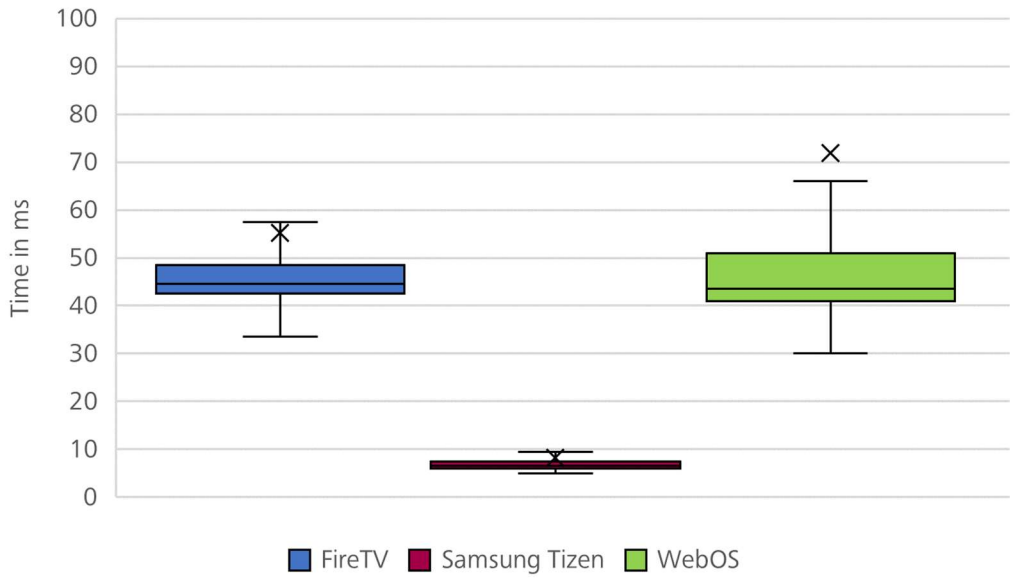

Figure 4-6: Results of the single message time (second to first screen) in the range up to 100 milliseconds. Outliers are not displayed for better legibility.

Abstraction penalty

Abstraction penalty (AP) describes the longer execution time of the added abstraction layer in comparison to the underlying technology (Brzozowski et al., 2011, p. 10). This factor was recorded by adding time stamps to the sent messages at each passing station in the SDK. Thereby the *round time* of the messages was evaluated, because incoming messages in the SDK should also be taken into account. The total average round times and the recorded partial times at the single stations are displayed in Table 4-9.

Average Times (n=36000)	FireTV	Samsung Tizen	WebOS
Total Round Time	110.41	16.44	143.87
Interface to Native Layer (AP)	0.13	0,15	0,13
Outside of SDK	110.25	16.26	141.56
Native Layer to Interface (AP)	0.02	0.022	2.17

Table 4-9: Total round times with average partial times at the different positions in the 2ndS SKD.

Influence of abstraction penalty

Overall, the abstraction penalty is only a small fraction of the total time for all three layers. Most of the time is spent outside of the SDK and is therefore outside of the *abstraction penalty* and the direct sphere of influence. The exact composition of this time cannot be determined within the scope of this test, but the partial steps are the processing of the *communication server* on the way there and back, as well as the processing and response on the *first screen platform* application. Figure 4-7 gives an overview of the small influence of the abstraction penalty on the total message time.

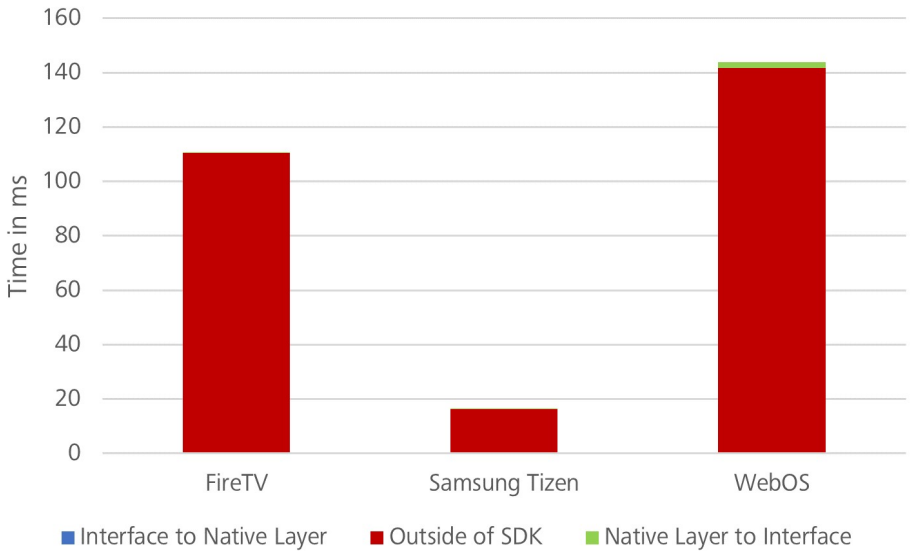

Figure 4-7: Visualization of the influence of the abstraction penalty on the total message time.

4.4.3 Fulfillment of Requirements

The raised requirements were divided in *functional* and *non-functional* requirements, and within the *non-functional* in *software quality attributes* for better overview. In the following, the fulfillment of the single requirements are presented in the respective subcategories:

4.4.3.1 *Functional Requirements*

Connection

The connection process consists of *discovering* compatible devices in the local network (F01), remotely *launching* the corresponding application (F02), and establishing a *connection* between the two parts (F03). All three aspects worked reliably in every case, both in the conducted evaluation (cf. Chapter 4.4.1) as well as in the prototypes (cf. Chapter 5) with the corresponding evaluations. In the here presented evaluation, the connection worked reliably, so that *connection losses* (F04) could not be recognized, but in a series of deliberate cuts of the Internet connection, the connection failures were always detected by the application.

Communication

The 2ndS SDK offers next to an open communication with *Strings* (F06) the ability to send and receive commands and events for a standardized communication (F05). These *JSON* based *SecondScreenCommands* are defined in the SDK and are easy processable within the different layers. These commands can be adapted within the SDK to the current context of the application. The structure of the communication layers allows the SDK to communicate with multiple devices simultaneously (F07).

Architecture

The SDK is available for *Android* as external module library and for *iOS* as a framework in the form of embedded binaries, which allows an uncomplicated integration (F08) for these platforms and the use in cross-platform approaches such as *Apache Cordova*[37] or *Xamarin*[38]. The modular and layered architecture with an OS-decoupled interface layer allows the SDK to be extended to support additional first screen platforms (F010) and to address each of these platforms separately (F09), as it was done in the evaluation to enable flexible and scalable deployment scenarios.

[37] https://cordova.apache.org
[38] https://docs.microsoft.com/de-de/xamarin

Other

The modular structure of the SDK allows the connection to different device types to be established *simultaneously* (F11), thus enabling cross-platform second screen applications. The 2ndS SDK has a *unified interface* (F12) that abstracts the underlying solutions and custom *SecondScreenExceptions* (F13), which aim to simplify the development process. For the use of the SDK, an *API documentation* with code examples was created (F14), and a *technical documentation* (F15) for better maintainability and extensibility.

4.4.3.2 *Non-Functional Requirements*

Performance

The results of the evaluation (cf. Chapter 4.4.2) have shown, that the SDK provides reliable and performant communication with an acceptable delay for a seamless interaction between the connected devices (NF01), within the SDK itself (NF02), and in the processing of the transactions (NF03).

Market Coverage

The SDK is available for most distributed mobile platforms (NF04), *Android* and *iOS*, which combined possess near complete market coverage (IDC, 2018). An accurate estimate of the distribution of first screen platforms is difficult to obtain, especially in a fragmented and rapidly changing market as this. The prioritization of *Samsung Tizen*, *Amazon FireTV*, *LG WebOS*, and *Android TV* was chosen after an calculation of the project partner *MEKmedia* as the currently most important platforms, according to their download numbers (NF05). Although problems with the support of some *Android TV* manufacturer were encountered in the development (cf. Chapter 4.1.2.5), the selected platforms represent an as broad a spectrum as possible at the time of realization. Future developments in the first screen market may need to be addressed at some point, but the SDK design was deliberately designed for these extensions.

4.4.3.3 *Software Quality Attributes*

Reliability

During the evaluation the test applications proved to be stable (SQ01) and error safe (SQ02), also in terms of the connection (SQ03 & SQ04).

Maintainability

The maintainability of the SDK is ensured by a modular architecture with layers for a clear separation of application logic (SQ05), comments within the code for better understanding (SQ06), and custom exceptions (SQ07), which are able to report the location and error types.

Usability

The connection process between the first and second screen was designed to work as straightforward as possible without the exchange of IP addresses, security codes (SQ09), or a registration process (SQ08), to increase the usability of the SDK and the resulting applications. In addition, the development process for the developers was simplified by creating one unified approach to discover, connect, and communicate between the first and second screen, compared to the different existing solutions (SQ10).

4.5 Conclusion

Conclusion in design science research

The *conclusion phase* at the end of a research cycle or a specific research effort is the last step in a design science research process. In this context, the focus is consolidating the undergone *process* and the *results* (Vaishnavi & Kuechler, 2015, p. 17), which ultimately also takes place through this work. This essential part of all research approaches (Hevner et al., 2004, p. 90). The output of the carried out design science research is a contribution classified as *improvement* (cf. Chapter 3.2), as the 2ndS SDK represents a better solution for a known problem (Gregor & Hevner, 2013, p. 346).

Addressed problem

The addressed problem is the *double multi-platform problem* occurring in the development of second screen applications. It is caused by a fragmented platform landscape on both the first and second screen side, which requires to redundantly

implement solutions for interacting with the corresponding application counterpart. This process currently increases the development effort for second screen applications.

Outlined solution

This work introduces a solution for addressing this problem in form of the 2ndS SDK. This SDK is a middleware framework available for the most distributed mobile platforms (*Android* and *iOS*) and allows the *discovery*, *launching*, and *communication* with common first screen platforms (*FireTV*, *Samsung Tizen*, *LG WebOS*). One of the aims thereby was not to create a completely new solution, but to build on the existing ones in order to ensure a seamless use. In this regard, a number of *functional* and *non-functional* requirements have been raised to ensure the quality of the resulting software.

Created solution

The SDK was developed to fulfill these requirements by, among others, implementing a modular layered architecture with one unified interface to abstract the complexity of the underlying first screen layers. Further central aspects were the extensibility by additional first screen layers, the provision of a unified communication process, and flexible deployment scenarios by individually initializable layers.

Evaluation

The development process consisted of multiple iteration, of which the result was evaluated in its ability to meet the previous defined requirements. In this order a test was conducted on with an *Android* application as second screen, and each a *FireTV*, *Samsung Tizen*, and *LG WebOS* application as first screen, to evaluate the SDK and in particular the communication. The results showed that a reliable and efficient exchange of information is possible in order to enable a seamless interaction of the different applications parts. In addition, it was shown that the abstraction of the underlying solutions does not cause a considerable penalty within the SDK. Overall, all requirements could be fulfilled and it was found that the 2ndS SDK is able to reduce the high development effort for second screen applications.

Further knowledge contributions

In addition to the contributions described here concerning the development of a cross-platform framework, the 2ndS SDK has led to further research on second screen interaction and the design of this type of applications, which are described in the third part of this dissertation (cf. Part III). The thereby obtained results have led to scientific publications (cf. Chapter 1.3) which again contribute to the existing knowledge base in this context. During the development of the SDK, multiple prototypes were created to demonstrate its functionality, which are described in the next chapter.

5 Created Prototypes

Demonstration of the artefact

In addition to the *conventional* activities in a design scientific research approach, Johannesson and Perjons (2014, p. 133) propose an additional step in which the use of the developed artefact is demonstrated. This approach is taken up in this chapter by presenting prototypes that have been created in the course of the undergoing. The aim was to examine either individual parts or the entire functionality of the 2ndS SDK, or to explore novel second screen use cases. These demonstrations also help to communicate the idea behind the artefact, show that it can really address the underlying problem, and can also be seen as weak form of evaluation (Johannesson & Perjons, 2014, p. 136). All prototypes presented here have been designed to provide a genuine second screen experience, i.e. they are fully functional within the intended scope, but still have different levels of maturity.

5.1 Tierwelt Live!

First prototype

The first prototype was chosen as a media library second screen application, as this use case is currently the most widespread. Prominent applications like *Amazon Prime Video*, *Netflix*, and *YouTube* are classified as this type. In addition, the technical feasibility of the concept of the 2ndS SDK was evaluated here, which is why the visual design was of secondary importance.

First implementation of connection process

This technical prototype consists of a cross-platform mobile application that is able to play media content on the second screen and search the local network for compatible first screen devices. When finding a device, the second screen could launch the associated first screen application and continue the media playback there. This process was derived from existing applications and guidelines from different manufactures, which later also formed the basis for the guidelines presented in this work (cf. Chapter 8). In case the associated application is not installed on the first screen, the attempt to establish a connection from the second screen will immediately refer to the corresponding download of the application. This eliminates the search process on the first screen and improves usability, replacing the associated cumbersome text input using a remote control with the

convenient interaction on a mobile device (Mu et al., 2015, p. 375). Figure 5-1 shows this first implementation of the connection process.

First implementation of connection footer

The connected second screen is able to control the content on the first screen and at the same allows the user to search for further content and additional information. Thereby the current connection status is displayed in the upper right corner and the title of the current content in a permanently visible footer as *control bar*. This control bar allows the navigation to a screen with associated information and additional controls of the current content. This approach proved to be essential to keep the constant control between the connected screens and at the same time ensure the functionality of the mobile application. Figure 5-2 shows the implementation of the control bar in the first prototype.

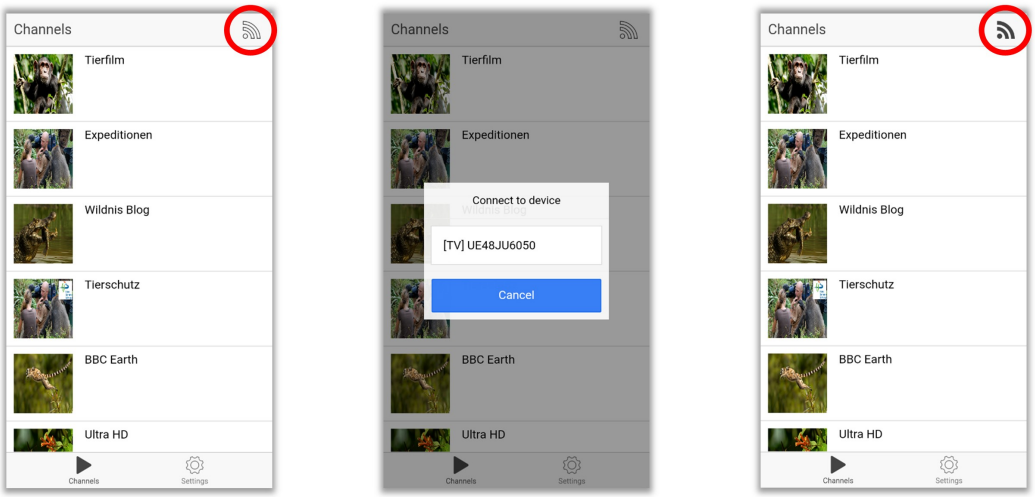

Figure 5-1: Connection process in the first prototype.

Technological realization

At the technological level, this prototype is implemented with the cross-platform tool *Apache Cordova*[39] and *Ionic*[40]. This cross-platform approach was rejected in the further course of the project due to a noticeably poorer performance compared to a native solution. The first screen platform is limited to *Samsung Tizen*, which laid the foundation for the SDK and was later extended to other platforms. The tech-

[39] https://cordova.apache.org/
[40] http://ionicframework.com/

nological and interaction concepts implemented for the first time in this prototype were further developed in the following iterations, foremost in the prototype *Audi MediaTV*.

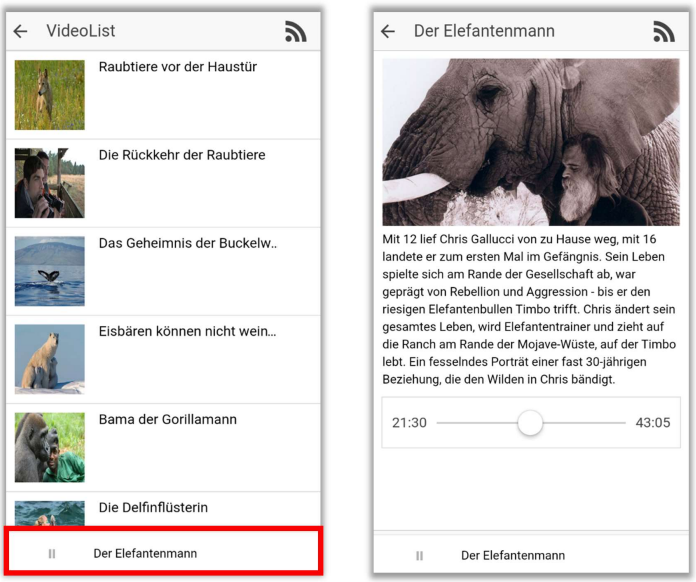

Figure 5-2: First implementation of the *control bar* to allow constant control between the connected devices and detailed view of current content.

5.2 Audi MediaTV

Re-implementation of the prototype

The aim of the second development cycle was to create a second screen application that is able to address multiple first screen platforms and has a higher degree of maturity in comparison to the first prototype. For this purpose, again a media library application was chosen, as this use case is highly relevant and had not yet been sufficiently investigated with the last prototype. At the technological level, this prototype was first implemented with the cross-platform tools *Apache Cordova* and *Ionic 2*[41]. In contrast to the first prototype, the newer and optimized version of Ionic was used to counteract the most significant disadvantages of cross-platform development: the poorer performance compared to native applications. Despite these efforts, the quality of the resulting prototype is noticeably lower in comparison to native applications, so the prototype was re-implemented for *Andoid* and *iOS*, leading to a considerably better result.

[41] http://ionicframework.com/

Function scope

The function scope was similar to the first prototype: the mobile application is able to *discover*, *launch*, and *communicate* with the corresponding first screen application, which represents the basic functionality of the SDK. Nevertheless, both application parts are also able to work independently. The concept of controlling the first screen via a mobile device using a control bar was adopted from the first prototype, further developed, and later integrated into the design guidelines (cf. Chapter 8). Figure 5-3 shows the connection process in the second prototype with discovered first screen platforms of different manufacturers.

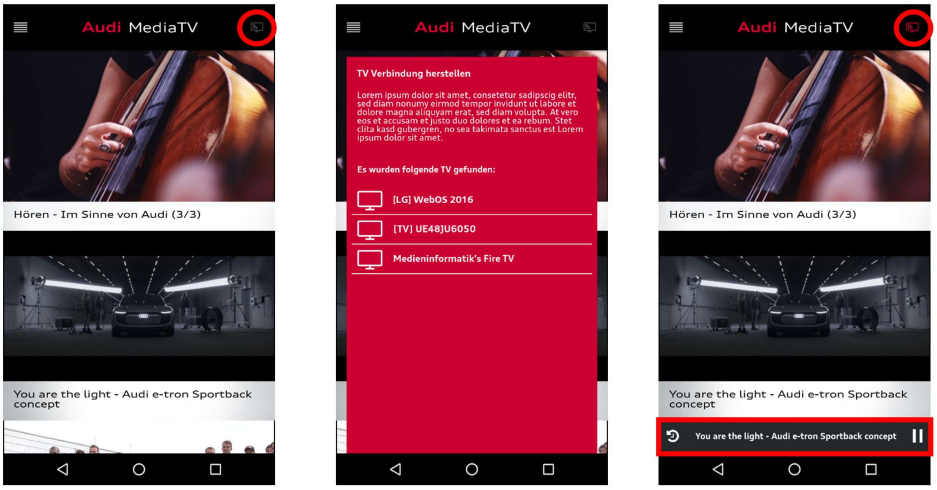

Figure 5-3: Connection process in Audi MediaTV with found devices of different manufacturers and implementation of *connection footer*.

Progress in the SDK through the development

The decisive difference to the first prototype is that the provided functionality is available for multiple first screen applications and the increase of the overall maturity of the 2ndS SDK. The architecture was completely revised and layers for *FireTV* and *WebOS* were added in addition to the existing *Samsung Tizen* layer. This stepwise and iterative creation of solutions for the individual platforms represented the main part of the SDK's development work and the result forms the basis for the final 2ndS SDK.

Differently adapted versions of the prototype were also the basis of some of the studies described later, such as the first attention direction study (cf. Chapter 7.2) and the validation of the heuristic checklist (cf. Chapter 9.4). The prototypes described in the following chapters serve the purpose of evaluating new second screen interaction concepts and less to the advance of the SDK.

5.3 Livestream Interaction

Live stream second screen content

Most of the content that comes to mind first in relation to second screen applications is pre-recorded, such as movies or series. However, there is also a wide range of applications for live events, such as sports events, entertainment events, or live streams of video game or similar content. Relevant application areas are *live voting* on the further course of the program, the parallel viewing of other camera *perspectives*, or the display of additional *information*, which are presented among others in the collected second screen application components (cf. Chapter 6).

Problem with current situation

The prototype[42] presented here aims to improve the interaction between a streamer and the viewers on both sides with a second screen application. Although the *communication* between streamer and viewer is an important part of the viewing experience, platforms like *Twitch*[43] only offer a basic form of to communicate, e.g. text based chats. Especially in large channels it becomes nearly impossible for the streamer and the viewers to get all the relevant information through the chat, due to the high number of messages (Lessel, Vielhauer, & Krüger, 2017, p. 1571). This problem is additionally aggravated by the shared attention of the streamer between the audience and the actual game content (Hamilton, Garretson, & Kerne, 2014, p. 1321). To find out the opinion of the majority of the viewers many streamers therefore use additional software to increase the interactivity with the viewers, like *StrawPoll*[44] (Lessel et al., 2017, p. 1571). However, these services only provide single functionalities, such as voting, and therefore multiple services must be used at once, which can be cumbersome to set up and manage.

Created prototype

In order to counteract these problems, a prototype was developed consisting of a mobile second screen application for the viewers and a web component for the streamer. The second screen part consists of an *Android* application that enables the viewers to participate in polls and raffles. The web component for the

[42] The creation of the prototype and its evaluation was part of the bachelor thesis of Bernhard Schweiger, which was supervised by the author.
[43] https://www.twitch.tv/
[44] https://www.strawpoll.me/

streamer allows the creation and evaluation of polls and raffles in real time, and the possibility to display the results directly in the live stream. The synchronization of both application components is enabled by a *Firebase*[45] database. The 2ndS SDK is not used for the creation of the prototype, because no external communication to web components was implemented at the time of creation.

User-centered design process and pre-study

This prototype was developed in a user-centered design process, in which the needs of viewers (n=5) and streamers (n=3) were qualitatively surveyed in interviews and revised by a quantitative survey (n=12845). The participants[46] rated polls and the ability to answer explicit questions as the most important features, which is why they were implemented alongside the raffle. Furthermore, it was found that the majority of viewers are generally participating in second screening activity (68.34%), which agrees with the results from literature (cf. Chapter 2.2.1.1), but explicitly refers here to context of live stream gaming.

Evaluation approach

The created prototype was evaluated in a real life test setting on Twitch. The livestream ran for about 100 minutes and had up to 770 viewers, who had the possibility to participate more directly by downloading the created second screen application. The streamer created a raffle and multiple polls on how to proceed in the stream. The questions and the results where directly embedded into the stream and up to 33 viewers participated. This rather low participant rate is presumably caused by the overhead of downloading an extra application and the passivity of the majority of viewers, which was confirmed in the pre-study[47]. After the stream, the participants were able to complete a survey regarding their experiences and the streamer was interviewed. The questionnaires used in the pre-study and for the final evaluation can be found in Appendix B.

Results evaluation

The questionnaire consisted of 5-point Likert scales (1 = totally disagree, 5 = totally agree), of which the results were summarized with one & two as *disagree*,

[45] https://firebase.google.com/

[46] n = 12845; average age: 17.0 years, standard deviation: 5.1 years; 98.7% male, 1.3% female

[47] 60.2% do not want to actively participate in live streams.

three as *neutral*, and four & five as *agree*. The survey[48] revealed that the participants were satisfied with the use of the application (3.9), had a feeling of participation (4.0), improved communication with the streamer (3.6), and influence on the further developments of the stream (4.1). The qualitative feedback from both sides also included mainly positive feedback regarding the concept and the desire for more comprehensive application cases. Negative feedback was mainly caused by the current user interface design of the second screen application.

Conclusion

The here introduced prototype represents an approach to increase the interaction between live streamers and their viewers by providing a unified framework for enhanced communication. The outlined design can be further developed to include additional functionally, ideally adapted to the needs of the individual streamers, games, or other context. The concept of the created prototype was approved by the participants on both sides and shows potential that is worth of further investigation. This approach represents a completely different concept of second screen applications, because instead of interacting directly with the stream, the interaction focuses on a counterpart in the background, which in turn interacts with the stream. This topic is suitable topic for further research.

5.4 WildLive

Project goals

Another prototype investigating new interaction possibilities enabled by second screen applications is *WildLive*[49], where animal documentaries on the first screen are supplemented in real time with additional information and gamified content, in form of a quiz, on the second screen. The aim was to create a system in which the two application parts complement each other and the advantages of the respective screen are used while both parts are being perceived as a uniform system. The main purpose of the project was to evaluate the concept developed, but also to estimate the effort required to produce the necessary content.

[48] n = 34; average age: 18.8 years, standard deviation: 4.2 years; 91.2% male, 8.8% female

[49] The creation of the prototype and its evaluation was part of the was part of the master course *Praxisseminar* project (SS 18) of Ariane Demleitner, Doris Ebenschwanger, and Julia Sageder, of which the author was stakeholder.

Technical realization

On the technical level, the prototype consisted of a web application as the first screen and an Android application as second screen. The connection and communication between the two parts was enabled by a version of the 2ndS SDK. The provision of external data, such as additional information and associated images, was enabled with *Google Firebase Services*. The additional content was mainly retrieved from *Wikipedia*, as the content is accessible and reusable through the creative common license[50]. The content on the first screen was embedded from *YouTube*, which enables a wide variety of potential use cases.

Function scope first screen

The use case of this prototype focused on zoological documentaries, as this type of content is widely available on *YouTube*, additional content can easily be created in this context, and it was assumed that users are easily interested in animals. The first screen application consisted of a map visualizing continents in different colors for a clustering of different video documentaries, as well as the current connection status and quiz score, which is displayed in Figure 5-4. However, the main task of the first screen is the playback of the selected videos.

Figure 5-4: First screen main screen with connection status, quiz score, and differently colored continents grouping the videos[51].

[50] https://creativecommons.org/licenses/?lang=en

[51] Figure taken from the project documentation of Ariane Demleitner, Julia Sageder, and Doris Ebenschwanger.

Function scope second screen

The extension by the second screen consisted of three functions: the control of the first screen, the provision of additional information, and gamified content in the form of a quiz. The additional information was synchronized to the timestamps of the animals appearing on the first screen and consisted of text and images and is classified as second screen application with high interaction (cf. Chapter 2.3.2). The text was deliberately kept short so as not to distract users too much, but more was available at the user's request (cf. Chapter 7.3). The previously displayed information can also be accessed via thumbnails of the corresponding animals. During advertisements the quiz on the second screen is triggered, which contains animal-related questions and a score of correctly answered questions. The current position in the video is visible through a progress bar at the bottom of the application, as were the controls of the first screen. Figure 5-5 shows two screenshots of the additional information and an example of the quiz on the second screen.

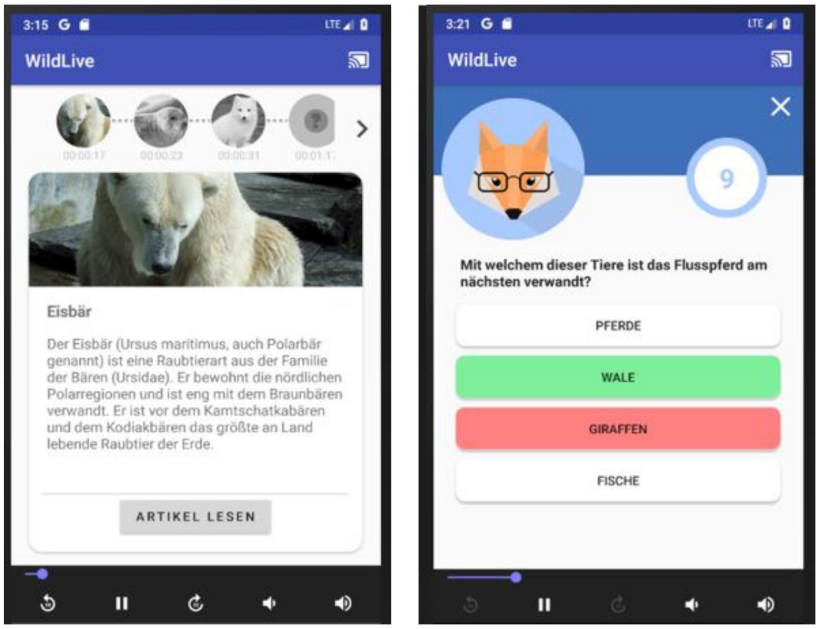

Figure 5-5: Implementation of the additional information and the quiz function on the second screen in WildLive[52].

Assessment of prototype

In an informal evaluation of the prototype, the concept was throughout assessed positively. Three experts were questioned about their assessment, who criticized some errors in the current implementation but found the approach to be very

[52] Figure taken from the project documentation of Ariane Demleitner, Julia Sageder, and Doris Ebenschwanger.

positive. In addition, elven participants tested the applications created, which they found appealing and informative. Negative issues mentioned were the consistency between the two screens and an unstable connection occurring. The resulting SUS score of 81.5, which is in the acceptable range (Bangor, Kortum, & Miller, 2009), underlines these assessments.

Conclusion

This prototype has shown that a second screen application can be a useful extension to deepen the connection to the first screen content and can be well implemented in existing infrastructures, but the embedding of content, for example from Wikipedia, still involves some effort. Furthermore, the evaluation of the application once again confirmed the importance of consistency and a smooth connection between the two application parts for second screen applications. The concept presented here can be transferred to other topics in future and the functionality of the two application parts can be extended, for example by components presented in Chapter 6.

5.5 Summary Prototypes

Aims of prototypes

This chapter presented four prototypes of functional second screen applications created in the context of this endeavor. The prototypes were developed to fulfill a variety of different objects, such as to proceed the development of the 2ndS SDK and ensure its functionality at all times, evaluate different forms of second screen interaction possibilities, or to serve as test objects for directly or later conducted studies on second screen behavior.

2ndS SDK has proven functional

The insights gained thereby show that second screen applications can offer a meaningful benefit and can be implemented within the framework of existing infrastructures. Especially the 2ndS SDK was proven functional and as basis for providing a satisfying second screen experience in multiple prototypes. The thereby identified important factors, a consistent design for the perception as a unified system and an error-free and fast connection between the application parts, have been incorporated into the later presented guidelines (cf. Chapter 8).

The second screen applications presented here also mark the transition to the next part of this dissertation: the optimization of second screen interaction, which addresses less a technical and more a conceptually level.

Part III – Optimization of Second Screen Interaction

Part III - Introduction

Structure Part III

Beyond offering a technical solution to establish a connection and communication between first and second screen platforms, this work provides insights on how to design second screen applications to optimize their use. This includes a systematic overview of possible features, which are referred to here as *application components* (cf. Chapter 6), insights into the attention behavior when using second screens (cf. Chapter 7), specific design guidelines (cf. Chapter 8), and a heuristic checklist for the efficient identification of typical problems (cf. Chapter 9). In combination, these findings provide comprehensive insights on what characterizes a satisfying second screen interaction and how to achieve it. Part III describes these parts, including the methodology applied, in the order given above.

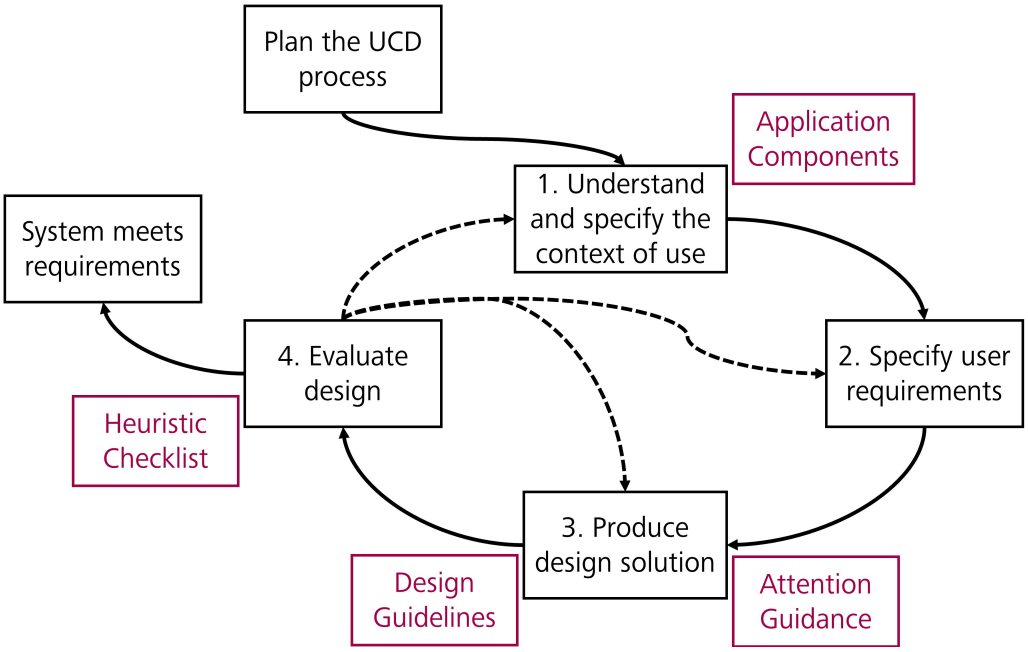

Figure Part III-1: Introduced insights on how to create a satisfying second screen experience in the user-centered design process (ISO, 2010).

The insights here presented on creating a satisfying second screen experience are intended to be used in a human-centered design process consisting of four central phases that represent an iterative process (ISO, 2010):

1. The *specification of context of use* is necessary both for the overall development and for the selection of application components (cf. Chapter 6).
2. *Specification of requirements* has no additional adaption for the context of second screen applications.
3. The findings on *attention guidance* (cf. Chapter 7) and the created *design guidelines* (cf. Chapter 8) are intended to support the *creation of the design solution* and *development process*.
4. The *heuristic checklist* for second screen applications (cf. Chapter 9) is used for the *evaluation of the created solution*.

6 Application Components for Second Screen Applications

Chapter structure

The benefits provided by second screen applications are very heterogeneous and were previously classified into five categories: *information*, *social*, *games*, *control*, and *other*, referred to as the ISGCO classification (cf. Chapter 2.3.1.2). These categories represent many different features that can be realized in second screen applications, which are referred to in this work as *applications components*. This chapter describes the interpretation of application components in the context of second screen applications (cf. Chapter 6.1), the methodology applied for the collection and validation (cf. 6.2), and the actual collection of components (cf. Chapter 6.3). These components are then evaluated in regard to the different program types and genres (cf. Chapter 6.4) and an instruction for the application of the components is presented (cf. Chapter 6.5) before the chapter is summarized (cf. Chapter 6.6).

6.1 Application Components in the Context of Second Screen

Application components

Application components in the context of second screen applications aim to create an additional value for users by different means. These are, however, always dependent on the current *content* and an emerging *need* of the user in the current application context. This relation is visualized in Figure 6-1.

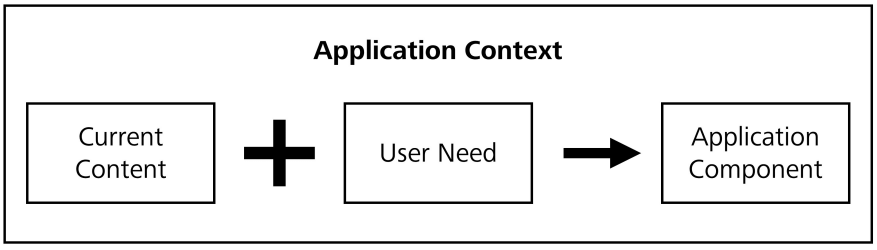

Figure 6-1: Relation of application components to current content, user need and application context[53].

Application context

The context of an application is understood as the "users, tasks, equipment […], and the physical and social environments in which a product is used" (ISO, 2010) and must always be taken into account when selecting application components.

[53] Figure adapted from the master's thesis of Eva-Maria Meier, supervised by the author.

In the literature and market analysis (cf. Chapter 2.1.1 & 2.1.2), significant differences were found between the possible contexts of second screen applications that need to be taken into account, e.g. news, movies, or live events.

User need

The features provided in these applications aim to satisfy certain needs of users, as the better understanding of the consumed content. The general reason for second screening is assumed to be linked to the viewers gratified feeling by multitasking because of the fulfillments of different needs (Gil de Zúñiga et al., 2015, p. 796).

Current content

These needs are usually dependent on the *current content*, which is also the trigger for many needs, e.g. the appearance of characters or plot events, and must therefore be considered at all times. This coordination of content and application components is examined later in detail in the guidance of attention in second screen applications (cf. Chapter 7). Previous studies have shown that the synchronization and relevance of the additional content of second screen applications heavily affects the user experience (Basapur et al., 2011, p. 130), which underlines the need for the adequate selection of application components. Possible components and their selection is covered by the following chapters.

6.2 Mixed Method Approach to Collect and Validate the Application Components

Prior approaches in literature

Previous studies in this field used different approaches to gain insights on second screen behavior, such as *qualitative* methods as interviews[54], diary studies[55], or focus groups[56]. These approaches are suitable to generate open-end findings in the users own words on their perception of different topics. In contrast, *quantitative*

[54] D'heer et al. (2012); Neate et al. (2015a); Basapur et al. (2012)
[55] Hess et al. (2011)
[56] Cruickshank et al. (2007)

*m*ethods such as questionnaires[57] or observation[58], which are common among literature, provide closed-end data that allows statistical analyzing (Creswell & Plano Clark, 2007, p. 6).

Mixed methods

The combination of these quantitative and qualitative approaches are referred to as *mixed methods research*, and were also found in the context of second screening[59]. This approach aims to provide better understanding on complex problems that either data alone cannot provide and is defined by Creswell and Plano Clark (2007, p. 5) as the following:

> *Mixed methods research* […] focuses on collecting, analyzing, and mixing both quantitative and qualitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone.

Exploratory design approach

This work uses an *exploratory design* approach, in which the later quantitative methods are based on the earlier qualitative and is suitable for the identification and generalization of mostly unknown variables (Creswell & Plano Clark, 2007, p. 75). In this approach, qualitative data is collected and analyzed to develop a classification system, e.g. the application components, which is supplemented by quantitative data provided here by a survey. Figure 6-2 provides an overview of the undergone steps of identifying and validating the application components of second screen applications.

[57] Busemann and Tippelt (2014); Courtois and D'heer (2012); Johnen and Stark (2015); Abreu et al. (2013); Gil de Zúñiga et al. (2015); Lowenstein-Barkai and Lev-On (2018); Huber et al. (2017)
[58] Shokrpour and Darnell (2017); Geerts et al. (2014)
[59] Tsekleves et al. (2009); Holz et al. (2015); Vanattenhoven and Geerts (2017)

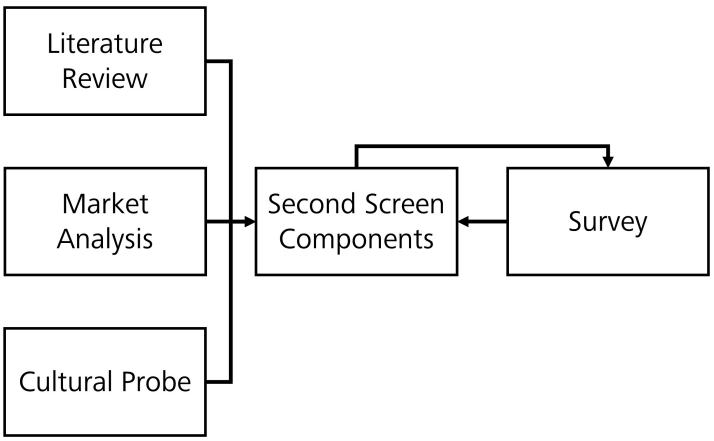

Figure 6-2: Simplified exploratory mixed methods approach for the collection and validation of second screen application components (Creswell & Plano Clark, 2007, pp. 58–79).

Components identified in literature and market analysis

The systematic review of literature (cf. Chapter 2.1.1) contained insights on the amount, type of activity, and background of second screening and identified many application components in this regard. The components themselves are regarded as qualitative data and the frequency of occurrence as quantitative data. The components collected in the SRL were supplemented by the findings of the market analysis of commercial second screen applications (cf. Chapter 2.1.2). Most of the identified features described in literature and in commercial applications provided an informational benefit, followed by control, and social features. This distribution is described in detail in Chapter 2.3.

Supplement of cultural probe

These application components were further supplemented with the qualitative perspective of users collected in a cultural probe[60]. The resulting collection of application components was further validated by a quantitative online survey[60] in which the individual components were evaluated within a specific context. The cultural probe and validation survey carried out is described in the following chapter.

[60] The identification of application components was part of the master's thesis of Eva-Maria Meier who conducted the cultural probe and online survey, supervised by the author.

6.2.1 A Cultural Probe of Second Screen Behavior

Origin of cultural probes

Cultural Probes were first introduced by Gaver, Dunne, and Pacenti (1999) with the aim to establish a personal communication to elders and to create the opportunity for them to explore life as *homo ludens*, humanity defined by its playful qualities. These first boxed contained postcards with questions, maps to highlight important areas, cameras to photograph things of interest, and other *playful* artefacts to gain insights on the participants' local culture.

Adaption of cultural probes

This approach was first intended to inspire design and was later adapted to gather data in a subtle and playful manner in sensitive settings, such as former psychiatric patients, elderly, or disabled people living at home without being intrusive, disruptive, or inappropriate (Crabtree et al., 2003, p. 4).

Benefits of cultural probes

These aspects are also important when it comes to generating authentic insights on actual second screen behavior. Laboratory studies[61] are widely spread in literature and are a suitable method for evaluating controlled situations, but it also important to extend these insights with data from natural environments and at the time of occurrence in order to be as precise as possible. Surveys[62] are often used in literature to measure second screen activity, but may not be representative because it is difficult to assess one's own behavior correctly in questionnaires, especially if they are not completed at the time of the activity. (Lazar et al., 2010, p. 101). In the literature, the estimation of second screen activity was found to vary greatly, which could be due to this reason (cf. Chapter 2.2.1.1). Only little of the research done so far in this area has investigated what people actually do while watching television in their natural home environment (Shokrpour & Darnell, 2017, p. 12). One method used to observe natural second screen behavior is to place cameras in the living room of the participant (Geerts et al., 2014; Shokrpour & Darnell, 2017). This approach offers the opportunity to gain rich

[61] Abreu et al. (2013); Abreu, Almeida, and Silva (2016); Almeida et al. (2015); Angeluci et al. (2017); Anstead et al. (2014); Brown et al. (2014); Cesar et al. (2008); Geerts et al. (2008); Mu et al. (2015); Neate et al. (2016); Neate et al. (2015b); Obrist et al. (2009); Pagno et al. (2015); Regal et al. (2013); Silva et al. (2015); Neate et al. (2017)

[62] Busemann and Tippelt (2014); Courtois and D'heer (2012); Johnen and Stark (2015); Abreu et al. (2013); Gil de Zúñiga et al. (2015); Lowenstein-Barkai and Lev-On (2018)

qualitative insight on second screen behavior, but also represents an intrusion on the users′ privacy that could influence the observed behavior. Therefore, a cultural probe was chosen to raise authentic data in a natural environment in a playful manner without affecting the observed behavior with an overly intrusive, disruptive, or inappropriate approach.

Content of the cultural probes

The materials of the cultural probe were aesthetically crafted and not too professionally finished, which gave them a personal and informal feeling allowing the participants to avoid the genres of official forms and commercial marketing (Gaver et al., 1999, p. 26). The content of the probe was adapted to the research domain and consisted of the following materials (Gaver et al., 1999; Leeuwen, Karnik, & Keane, 2011; Lucero, Lashina, Diederiks, & Mattelmäki, 2007; Robertson, 2008):

- An introduction on the materials of the box.
- A profile for personal information.
- A personal diary to record the viewing behavior.
- A sticker book for recording of the used applications.
- An instruction for a photo shooting of the participants surroundings.
- Fill-out-graphs for television usage habits.
- A questionnaire for the behavior during commercial breaks.
- A questionnaire for the viewing behavior in groups.
- Paper mockups of smartphones for generating new ideas for application components.

Goal of the cultural probes study

All the mentioned materials were tangible and to completed on paper except the photo shooting, which was done with the participants' smartphone and sent to test administer out of simplicity. The materials of the cultural probe are describe in more detail in Appendix C.1. Figure 6-3 shows a sample kit of the created cultural probe with the paper mockups of smartphones. Goal of this study was to gain authentic insights on the actual television and second screen behavior and qualitatively identify needs of users, which application components can fulfill.

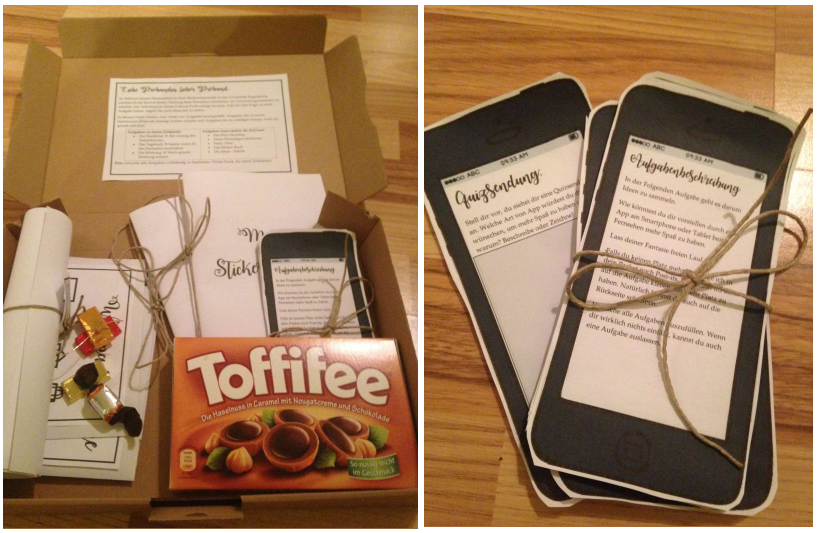

Figure 6-3: Sample kit of the cultural probe with paper mockups[63].

Pretest & study

A pretest was conducted in which one participant (female, 24) completed the tasks of the probe with a think-aloud-methodology in the presence of a moderator to avoid misinterpretations or errors in the cultural probe. The feedback was incorporated and again presented to the participant before the final study was launched. In the actual study, the participants inspected their probes with a moderator and got an introduction to the individual tasks. The study was carried out over a period of three weeks.

Test participants

19 participants (seven male, 12 female) in 14 homes completed the tasks in the cultural probe. The average age was 27 years, with a range of 26 years. Most of the tested subjects live in a partnership (12), three in a shared apartment, two with their families, and another two live alone. The participants were chosen to represent an age spectrum as wide as possible and to have some participants of the most common household forms, even though participants in partnerships are overrepresented in this sample.

The more general insights gained by the cultural probe are presented in Chapter 2.4 for better overview with the other results on second screen behavior and the raised application components in Chapter 6.3. In the following the validation process of the found application components is described, which states the last step in the applied exploratory mixed methods design.

[63] Figure taken from the master's thesis of Eva-Maria Meier, supervised by the author.

6.2.2 Validation of the Raised Application Components

Validity in mixed methods research

The understanding of *validity* differs in quantitative and qualitative research. In *quantitative* research, validity means that a meaningful inference from the gained results to a population can be drawn. In *qualitative* research, validity states whether the raised data from the participants is accurate, can be trusted, and is credible (Creswell & Plano Clark, 2007, 133f.). This tension between the different interpretations of validity is one of the major issues in mixed method research, but is interpreted here as the ability to draw meaningful and accurate conclusions from all of the data in the study (Creswell & Plano Clark, 2007, p. 143). Each methodology applied in the mixed methods design, e.g. the SRL, market analysis, and cultural probe, improves the validity of the raised application components by the principle of *triangulation*. Triangulation describes the viewing of the same phenomenon from different perspectives by using different research methods and sources of data (Johannesson & Perjons, 2014, p. 55). In order to further increase the validity of the identified components, a final quantitative approach in form of a survey was applied to complete the up to now predominantly qualitative data.

Surveys and questionnaires

Surveys are one of the most commonly used methods across all fields of research and are well suited to quickly obtain a large number of responses and provide an overview of specific topics. Therefore, a survey on the prior raised application components was selected as the as the final step in the mixed methods approach. A *survey* is a well-defined set of questions to which individuals are asked to respond. For differentiation, a *questionnaire* is the list of questions, and the *survey* is the complete methodological approach (Lazar et al., 2010, p. 100). The data collected with this methodology is typically less in-depth and might be biased, as it is often difficult to assess one's own behavior correctly in a questionnaire. Also participants usually fill in the data without the presence of a moderator, which can provide clarification if necessary, which also potentially affects the quality of the data. To counteract these problems, the questionnaire needs to be well structured, the questions well chosen, and tested before the survey is launched.

Survey on Second Screen Application Components

The structure of the questionnaire was divided in multiple sections: An introduction and several main parts in which the components are assessed in regard to certain genres. The introduction included the following aspects:

Introduction of the questionnaire

- Context of the survey
- A short explanation of the research domain *second screen*
- A statement of the researched problem
- The request for truthful answers
- The promise of anonymity
- Thanks for participating the questionnaire
- An estimated processing time
- Demographic data and TV consume

Main part of the questionnaire

In order to assess the raised application components, a *standardized questionnaire* was chosen to collect quantitative data (Döring & Bortz, 2016, p. 399). The closed questions had given answers consisting of the identified components in the context of certain genres and only a few open answers to supplement the previous components. These questions were as specific as possible to aim at single research aspects. Before the concrete components were evaluated, the second section questioned the general second screen behavior of the participants and the third section an evaluation of specific aspects of the ISGCO classification (*information*, *social*, *gaming*) in regard to their underlying motivations (*entertainment*, *relaxation*, *collaborative use*).

Assessment of application components, genre, and program type

The coordination of content type and application components has been identified as a crucial factor of achieving a satisfying user experience in previous studies (Basapur et al., 2011, p. 132; Geerts et al., 2008). For this reason, the participants of the survey were asked in the fourth section to rate the prior elected application components regarding different genre types, for example *fantasy*, *science fiction*, or *horror*. In addition to the genre, the application components were assessed to different program types, such as *documentary*, *movie*, *news*, etc. Previous studies in this area differentiated only a few genre types; this survey queried 16 program

types and nine genres in the questionnaire to provide a more comprehensive overview. Figure 6-4 gives an example of the assessment of application components and program types. The full questionnaire can be found in Appendix C.2.1.

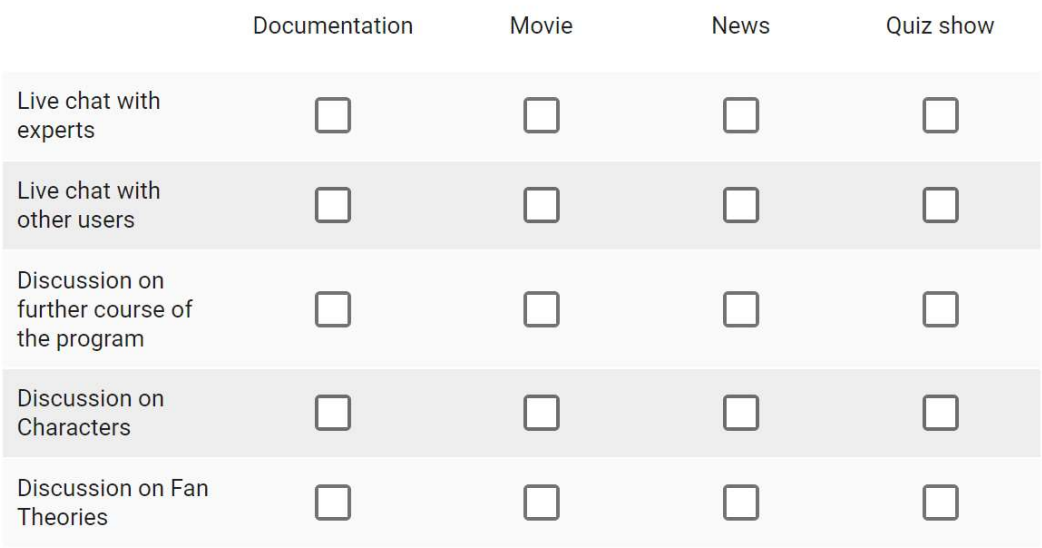

Figure 6-4: Example for assessment of application components and program types.

Pretest

A pretest of the created questionnaire was conducted with two participants (female, 21 & 48), who completed a think-aloud-walkthrough to check the comprehensibility, clarity, fatigue, leading questions, and duration of the questionnaire (Döring & Bortz, 2016, p. 405). Feedback regarding the phrasing of specific tasks and single questions was incorporated and shown to the participants for revision. As final step, an expert in the research domain reviewed the questionnaire for content-related correctness.

Conducting the survey

The survey was conducted online with of *Google Forms*[64], an online tool for collecting information via personalized surveys, and was accessible for 14 days. An online survey was chosen over paper questionnaires due to the better access to potential respondents, better cost-efficiency in terms of time and expenses, easier data analysis, and the lack of influence on the data whether the questionnaire is answered online or on paper (Lazar et al., 2010, 116f.). The survey was completed by 56 participants, 34 female and 22 male, the average age was 23.98 years,

[64] https://www.google.de/forms/about/

with a range of 35 years. The participants with no experience or interest in second screen applications in general were not included in the assessment of second screen components and content type, in order to avoid a falsification of the collected data. This allowed the collection of data of 31 participants (17 female and 14 male) with an average of 24.70 years, in a range of 35 years. The results of the survey are therefore not representative, but still offer valuable insights that need further validation in future work. The raised and validated application components are presented in the following chapter. A closer analysis of the differences of components and program genre and type is presented in Chapter 6.4.

6.3 Collection of Second Screen Application Components

Classification of application components

This chapter presents a collection of 55 application components for second screen applications, which were elicit and validated with a mixed methods approach, described in the previous chapter. These components are features that create an additional value for users, dependent on the current content and the emerging user´s need in a certain application context, as described in Chapter 6.1. The components presented here are seen as extensible collection, that summarizes the diverse benefits of second screen applications and aims to supports developers improve the quality and diversity of future applications. In order to provide a better overview on the heterogeneous aspects of second screen applications are the components categorized according to the ISGCO classification (cf. Chapter 2.3.1).

Combination of application components

The components of these categories are not to be seen isolated and complete each other well if they are correctly adapted to the current context and content. For example, *game* features can be combined with *social* and *informational* components to create a quiz that allows players to compete with their friends and improve their background knowledge of the current content. Figure 6-5 shows the classification of the raised application components. First, the components that provide an *informational* benefit are discussed, followed by the categories *social*, *gaming*, *control*, and *other*.

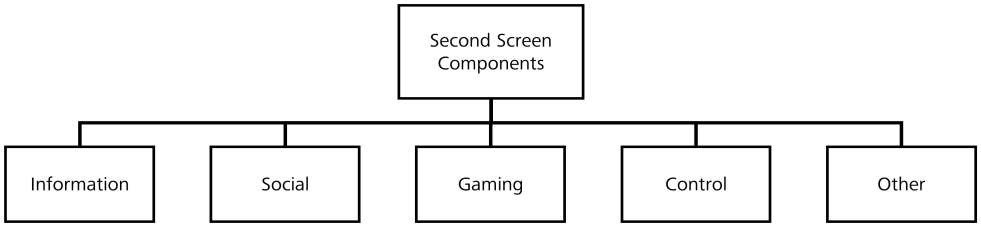

Figure 6-5: Distribution of the second screen components according to the ISGCO classification

6.3.1 Information Components

Meta and content information

The informational benefit of second screen applications appears to be the most natural feature for this type of application as it is the most widely distributed component among literature and commercial applications (cf. Chapter 2.3). The need for information is triggered by the current content within a particular context (cf. Chapter 6.1), e.g. the appearance of an actor or the lack of understanding of the current plot. This need can be met with the help of a second screen and is ideally anticipated by specific application components by providing information about the actor or background information on characters. This example also describes the division of additional information into the two subcategories: information on the actual content and meta-information. For example, meta-information refers to actors or filming locations, while content information refers to the displayed characters or fictitious locations. This distinction is not always as clear as in the above example, but is nonetheless seen as a valuable addition for a better clarification of informational benefits. Figure 6-6 shows the distinction between meta and content information with the according subcategories, which are described in detail in the following with the actual components and examples given:

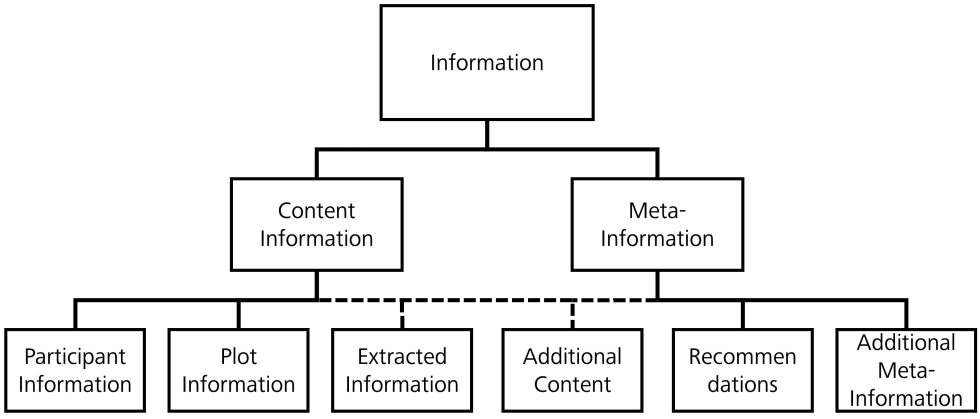

Figure 6-6: Distinction between meta and content information in application components with belonging subcategories.

Content Information

Content information adds value by providing information about the actual content for better accessibility and understanding, and has two distinct subcategories: *participants* and *plot* information as well as two shared subcategories, *extracted information* and *additional content*.

Participant Information:

- Participant appearance
- Background information on participants
- Relationships to other participants

Participant information

By providing information about *participants* in consumed content, such as characters in movies or athletes in sports events, viewers are able to gain better access to complex content such as *Game of Thrones* (miniMapps, 2018), or keep track of live events (digame GmbH, 2018; UEFA, 2018). The appearance of participants on the first screen can be synchronized with the second screen to display background information or relationships with other participants and locations. Player positions in live sports is also a popular example of additional content information about participants.

Plot Information:

- Summaries of previous content
- Plot proceedings & timelines
- Maps

Plot information

In addition to information on *participants*, information on the *plot* of the content is valuable addition on the second screen. This can take the form of *summaries* of previous content, an overview on *proceedings* and *timelines*, or *maps* for better spatial understanding. With these components, the second screen offers the possibility of better understanding, accessibility, and individualization, especially for more complex content.

Extracted Information:

- Clothing
- Recipes
- Instructions (Do-It-Yourself)
- Dates

Extracted information

Information contained in the current program can be extracted to the second screen for better access, e.g. *recipes* of food presented in the show, *clothes* worn, or *dates* for upcoming events or the next show, which can be integrated directly into the calendar of the second screen. This extracted information can also be combined with shopping components presented in the *other* category. Depending on the context, extracted information can also be classified into *meta information*. For example, in a cooking show recipes are directly related to the content, while cook-a-likes of fantasy shows are not.

Additional Content:

- Outtakes
- Behind-the-scenes
- Interviews with actors & directors
- Replays and different camera perspectives
- News & updates
- Visualizations & Visual Aids

Additional content

Additional content offers the opportunity to gain new perspectives on content, e.g. in form of *outtakes*, *behind-the-scenes*, *interviews* with actors or directors, or other *news* and *updates*. These aspects are considered as *meta* because they go beyond the scope of the actual content and the participants appear out of character.

R*eplays* and *different camera angles* in live shows or sports events (ZDFonline, 2018), on the other hand, complement the actual content and enable the viewer to individualize the previously linear experience on his second screen according to their preferences, without interruptions or missing parts on the first screen. Furthermore, *visualizations* on the second screen can be accessible for closer examination and better understanding of complex content.

Meta Information

Meta information refers to data *outside* of the actual content. In the following the subcategories of meta information, *recommendations* and *additional meta information*, are presented:

Recommendations:

- Related topics
- Related genres
- Related program types (e.g. movies or shows)
- Friend recommendations & watch list
- Next episode & movie

Recommendations

Recommendations is a feature that is already widely used. Media applications typically suggest videos on *topics*, *genres*, or *program types* (Amazon Mobile LLC, 2018; Netflix, 2018; Twitch Interactive, 2018). Some providers also offer *recommendations* and *watch lists* from friends, which several users found to be a valuable addition, if the content could be consumed anonymously. The automatic playback of the next episode after a short time is a standard feature for TV shows with most media applications and is appreciated by users as a benefit.

Additional Meta Information:

- Music
- Film locations
- Actors
- Information on the next show
- Trivia
- Facts and numbers

Additional meta information

Additional meta information provides background information that might be of interest to users, such as featured *music* with corresponding title and artist. This can be combined with the possibility to listen to the song directly or integrate it in other services, such as *Spotify*[65], and can be displayed either directly at occurrence or as complete overview of all songs. *Film locations* can be linked to *TripAdvisor*[66] for further background information or travel planning. Short biographies of *actors* as well as featured movies can be shown directly at their appearance for convenience. *Information on the next show* or *event*, release dates, and information on progress of the shooting with according videos are also desired features for second screen applications. *Trivia* or *facts and numbers* can be displayed at appropriate times, on demand, or as quizzes or polls with other users, combining multiple features such as *informational*, *gaming*, and *social* components.

6.3.2 Social Components

Social components allow users to share their first screen experience with others by using a second screen. These include *discussions*, *live chats*, and *social network integrations.* Sharing information with other users is well suited for second screens because text input is significantly more performant with second screen devices than with traditional remote controls (Mu et al., 2015, p. 375). It is assumed that the consumption of text on second screens is also preferred by users as it improves readability and reduces interruptions on the first screen. The subcategories of the raised social application components are shown in Figure 6-7 and are presented below:

[65] https://www.spotify.com
[66] https://www.tripadvisor.com

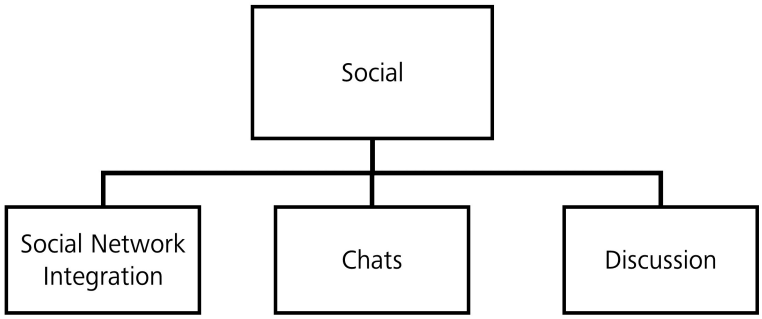

Figure 6-7: Subcategories of social application components.

Social Network Integration:

- Content
- Participants

Social network integration

The key to success of many application components lies in avoiding the creation of isolated solutions and building on the existing infrastructure, such as highly distributed social networks. Most of the current *content* and *participants* are represented on *Facebook*[67], *Twitter*[68], and *Instagram*[69], which can be integrated directly into second screen applications with the intent to provide users with a sense of inclusion and actuality.

Chats:

- Friends
- Participants
- Other viewers
- Experts

Chats

Chats are suitable for the immediate exchange of information, which is usually used between two persons or in smaller groups, because especially in large channels it becomes almost impossible for the participants to get all relevant information (Lessel et al., 2017, p. 1571). Users can chat with *friends*, *participants*, *other viewer*, or *experts* about consumed content. This exchange of information is more volatile and sudden than the *discussion* component.

[67] https://www.facebook.com
[68] https://twitter.com
[69] https://www.instagram.com

Discussion:

- Further course of program
- Participants
- Content
- Fan theories

Discussion

The discussion about content on websites like *Reddit*[70], social networks, and friends in person is very common among many users, but the second screen could add a new dimension to this behavior. Users can discuss the *further course of the program*, which could be taken into account by content providers immediately or in the long term, and adapt the program more closely to the users' needs. Another topic of discussion are *participants*, such as actors or athletes, the *content* itself, and speculations about future content in form of *fan theories*. All components mentioned are possible in a public environment or in a selected circle of friends, depending on the context and preferences of the user. A good addition to these features are rating and voting systems or other *gamified* elements, which are presented in the next chapter.

6.3.3 Game Components

Game components are popular features to increase the bond between viewers and content. Users are able to deepen their knowledge, engage with others, or have their voices heard in a playful manner. Content providers, on the other hand, hope to maintain or even increase users' interest in the consumed content. Highly distributed components are *quizzes* and *votings*, but there are also *other*, more innovative features that are presented below:

[70] https://www.reddit.com

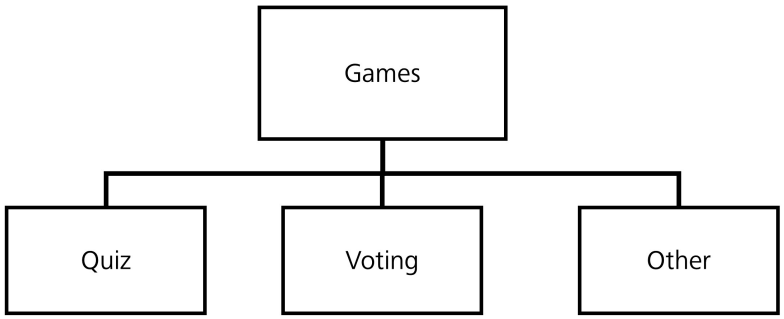

Figure 6-8: Subcategories of game application components.

Quiz:

- Content
- Commercials
- User generated content

Quiz

Quiz components allow users to further engage with consumed *content*, e.g. by answering questions related to a watched documentary or playing along in quiz shows to assess their own performance on the given questions. In this way, viewers can also contribute to live shows by playing with or against the participants of the show. Quizzes associated with *commercials* can reward users for watching and answering questions. The questions can also be generated by other *users* or friends who have consumed the same content. This is in turn a good example of the combination of *social* and *game* components that complete each other well. There are also different variations in the realization of quizzes, e.g. whether collaborative aspects are implemented. This may be a score displayed on the shared first screen or a more private approach, where the focus is placed only on the second screen. Previous studies have also shown that the majority of users consider quizzes as a desirable feature for second screens (Mu et al., 2015, p. 376).

Voting:

- Participants
- Plotlines
- Influencing

Voting

Voting components are persumably the best option of direct feedback, especially in large numbers. User can rate *participants* or *plotlines* directly and thus express their opinion, which is for example well suited for daily soaps with lots of content

and characters (RTL2 Fernsehen GmbH & Co. KG, 2018a, RTL2 Fernsehen GmbH & Co. KG, 2018b). Voting can also be used to *influence* the course or outcome of a show, for example when the winner is determined by the audience (digame GmbH, 2018).

Other gamified content:

- Puzzles
- Hide & seek games

Other gamified content

Besides quizzes and voting there many possibilities for future game elements on the second screen linked to the content. For example, *puzzle*s that consist of screenshots or other pieces of the first content that can be assembled on a second screen, which is also possible with collaborative features (Anstead et al., 2010). Another example are *hide and seek* features where private information, e.g. the person who hides, is displayed on the secondary device and shared information on the first screen (Emmerich et al., 2014). A popular approach for second screen games is the visualization on the first and the controls and additional or private information, such as individual player attributes, on the second device. This can also be assigned to the *control* aspect of second screens, which is discussed in the next section.

6.3.4 Control Components

The *control* aspect of second screens is the second most common after *information* and popular among literature, commercial applications, and actual users (cf. Chapter 2.3). The second screen has the potential to provide a more direct and versatile control of the first screen than traditional remote controls. Most second screens have the potential to become remote controls of the first screen, reducing the dependency on specific hardware and enabling collaborative usage scenarios, in which each user is able to control and contribute to the shared content of the first screen. The content controlled on the first screen typically refers to media content such as movies or TV shows, but there are also several application areas for games. Figure 6-9 shows the subcategories of control components.

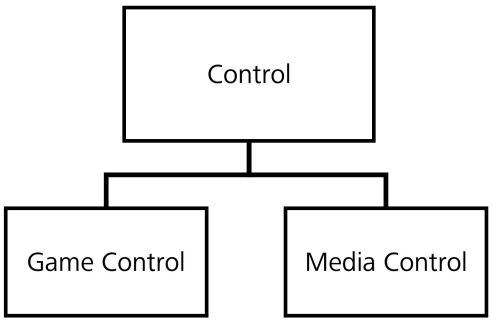

Figure 6-9: Subcategories of control application components.

Media Control:

- Content selection
- Content control
- Multi-user interaction

Media control

Most of the *control* activity on a second screen relates to the *media* content of the first screen. Users feel that the *content selection* is more direct and better accessible through the images provided, the descriptions are easier to read, and the search is more direct on the closer second screen device. This also applied to the actual *control* of the content, such as play, pause, volume, and time selection. Time selection is typically divided into short periods of time, implemented by buttons that jump 10 to 30 seconds forward or backward, and longer jumps, usually with a timeline and thumbnails of the targeted time (cf. Chapter 8.3). Another benefit is the asynchronous use of the second screen control. The content can be selected in advance or without staying in the same room, which creates more flexibility for the user. Furthermore, m*ultiple users* can simultaneously control the first screen or select content without being dependent on a single remote control, providing more flexibility.

Game Control:

- Private information on second screen
- Hardware independent
- Low-effort multiplayer

Game control

The benefits of second screens as controllers for games on the first screen are: additional *private information*, *independence from specific hardware*, and easy *multiplayer* usage. The availability of a display in the controller offers the possibility to store information that could overload the main user interface on the first screen or should not be seen by other players. Using the controller may also be easier to learn, as it can provide help instructions such as "*press this button now*". Additionally, the key mapping is more intuitive, as icons for the following action can be displayed instead of single letters, like it is common with traditional controllers. Another advantage is the *hardware independent* and *low-effort* character of second screen controllers. Instead of purchasing specific hardware, existing mobile devices of users can be used, which enables flexible player numbers up to the massive multiuser games (Weißker et al., 2016).

Missing hardware buttons

These benefits come at the expense of missing hardware buttons, making the touchscreen controller unsuitable for more complex input patterns without looking. However, not all game inputs consist of fast-paced button pressing, the touch controller can be superior in terms of text composition and consumption or precise selection processes. It is unlikely that second screen controller will replace traditional ones in all areas of gaming, but if all advantages and disadvantages are properly weighted, they can be a valuable addition.

6.3.5 Other Application Components

In many classifications, individual aspects do not match the categories provided. One solution to this problem is to introduce a category in which these exceptions are collected. The previously presented application component categories reflect the most distributed aspects of second screening, but there are also examples that do not seem to fit the existing categories and are therefore assigned to the *other* category. This category is also designed to include future components of second screen applications that are difficult to predict. The existing subcategories of *advertisement* and *shopping* are also considered highly innovative, but also much less widespread.

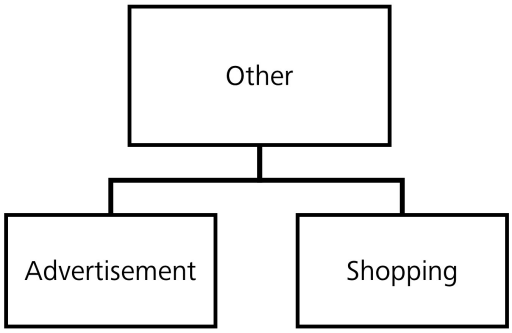

Figure 6-10: Subcategories of other application components.

Advertisement:

- Further Information
- Personalized Advertisement

Advertise-ment

By linking *advertising* on the first screen with the second screen, users can take advantage of advertising offers directly and obtain *further information* about articles viewed without additional research. In addition, the advertising seen can be better targeted at the needs of users and thus be perceived as more relevant. Users generally tend to be skeptical about this type of *personalized advertisement* as they may see it as an invasion of their privacy. Therefore, further research in this area is needed to investigate the acceptance of users of this type of second screen component.

Shopping:

- Linked Articles
- Payment

Shopping

Second screen applications can also offer the ability to purchase articles that are related to the current content on the first screen. This could be clothing or accessories worn by characters in movies, or items from a cooking show. If the *payment* is also possible with the mobile device, second screens could become a seamless connection for shopping in this context.

6.4 Evaluation of Application Components in Different Genres and Program Types

Assessment of components and content type

The benefits provided by the application components introduced in the last chapter are very heterogeneous. In order to assess the combination of the various benefits and different content types, an online survey was conducted in which the single components and potential program types and genres were matched (cf. Chapter 6.2.2). This study confirmed that the suitability of second screen application components differ from the type of the content.

Validation of application components

In addition to the relation between application components and different contents, the survey also aimed to validate the raised components themselves. Instead of a direct evaluation of the components, which was difficult for the participants to assess due to the diversity of different contexts, it was assumed that if components received votes by the participants, it is esteemed as desirable and therefore relevant. Overall, each proposed application component was considered desirable in a given context, even if some components, such as *chats* with friends or *background information* on characters, received far more votes than components, such as a direct *shopping* of articles related to the content.

Applied evaluation approach

Nine types of program genres, 16 program types, and 49 of the prior elicit application components were examined in the study. Control components were excluded from the evaluation due to their purely practical nature and their cross-program type and genre applicability. For a better overview, the components are summarized according to their categories, *information*, *social*, *game,* and *other* in the following. The participants were also able to select that none of the given components are considered fitting in this context and that they are not interested in this particular genre or program type, which responses are combined in the *no interest* category.

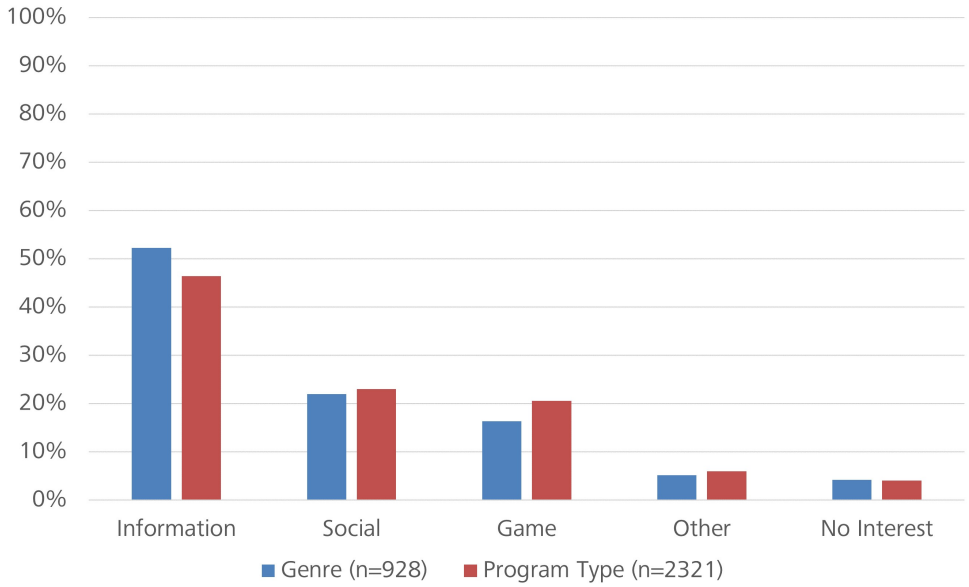

Figure 6-11: Distribution of desired components categories in program types and genres.

Distribution of component categories

Overall, *information* components are the most desired among all genres and program types, followed by *social* and *game* features. The *other* and *no interest* category show an almost insignificant low distribution in this survey, which is shown in Figure 6-11. These results generally agree with the distribution found in the literature review and market analysis (cf. Chapter 2.3), when control aspects are not considered. The accordance of desired und existing features confirm that *informational* aspects are the most important of second screen applications, followed almost equally by *social* and *game* aspects. In the following particular noticeable findings are presented, the complete results of the survey are found in Appendix C.2.2.

6.4.1 Application Components and Program Genres

The survey found strong variances in the suitability of application components among different genre types, as Figure 6-12 shows.

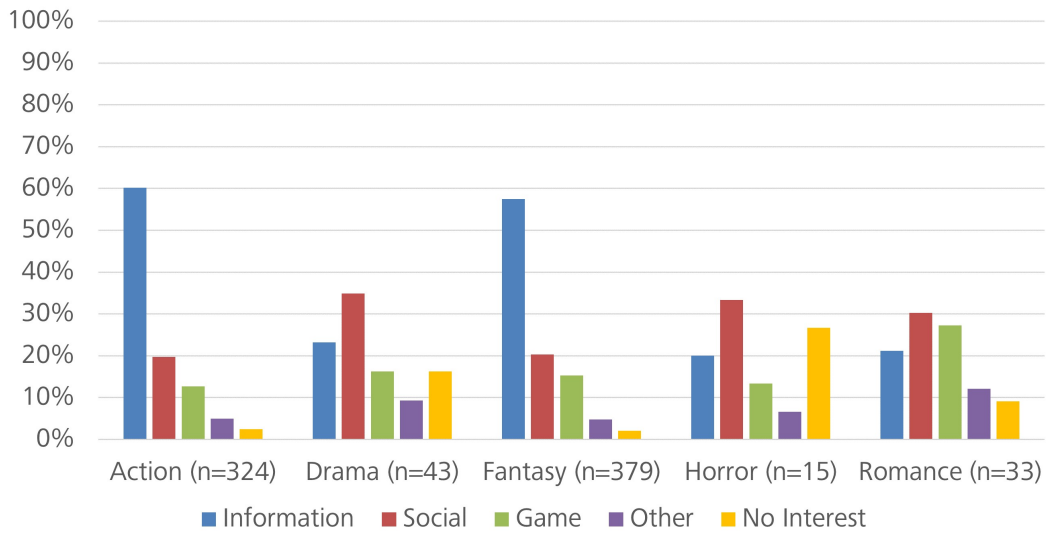

Figure 6-12: Selected ratings of application components, classified by their categories and genres.

Application components and genres

The high difference between the numbers of response and *no interest* responses between the genres surveyed conclude that the participants have a mixed interest in second screen features, dependent on the current content type. For example, in *horror* or *drama* genres, which tend to have a higher level of immersion among viewers, second screen features that can lead to a loss of this immersion are less desirable than in *action* or *fantasy* content. In these content types, users also have a noticeably bigger need for additional information, possibly because of more complex characters and story lines. In *romantic* content, on the other hand, especially *social* features are desired that enable users to share their current experience with others. In addition to the rather high-level differences in genres, different program types were surveyed, which is presented in the following.

6.4.2 Application Components and Program Types

Similar to the program genres, the suitability of application components depends on the type of the program. Figure 6-13 shows a selection of evaluations for different program types and categories of application components.

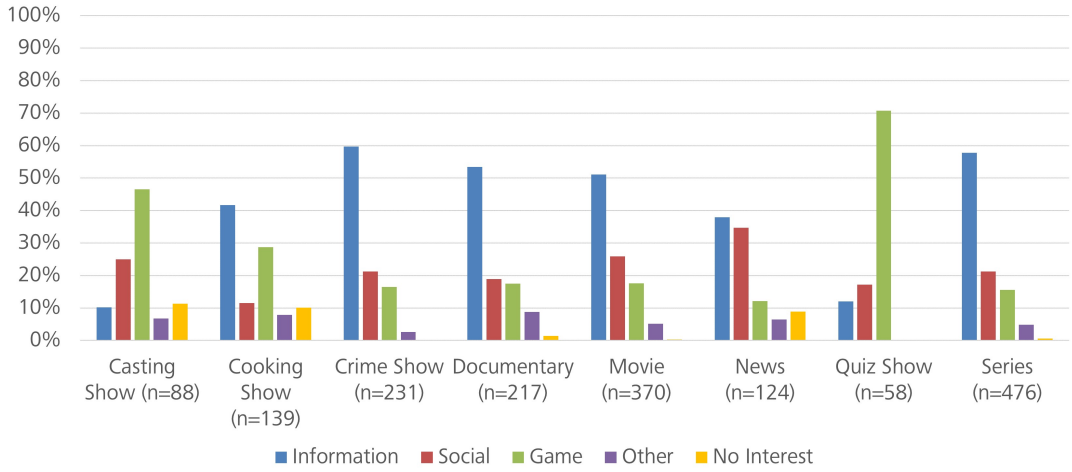

Figure 6-13: Selected ratings of application components, classified by their categories and program types.

Application components and program types

Information components are suitable, for example, for *movies* and *series* in which the focus is on characters and progressive storylines, but also for content that already has an informative character, such as *documentaries* or *crime shows*, in which the second screen can provide visual aids or additional background information. *Social* features are seen as addition to multiple program types, but are less distinctive overall. The need to share current experiences with others is particularly relevant with *talk shows*, *news*, or *casting shows*. *Game* components are especially popular for live events such as *casting*, *cooking*, *quiz*, or other *game shows*. The program types *movies* and *series* received the most votes and are therefore estimated as the most popular, and have a high potential for second screen features.

6.5 Instructions on How to Use Second Screen Components

The last chapters introduced application components of different categories and an evaluation regarding their suitability in different program types and genres. This chapter provides instructions on how to use the previously presented components.

In order to select appropriate application components, the designer needs to know the current *context*, *content*, and *target group* of the application. The guideline presented here is derived in several steps from the user-centered design process and is considered an iterative process (ISO, 2010).

1. **Define the content.** First, the content type of the second screen application must be selected. There are differences between different program types and genres (cf. Chapter 6.4) that need to be considered when selecting second screen components. In order to create a satisfying user experience, the components must be well adapted to the current content.
2. **Summarize possible components.** After the content has been defined, a selection of possible components can be assembled according to program type and genre. This collection can be narrowed down and prioritized in the next steps.
3. **Identify target group.** As with user-centered design, a comprehensive understanding of the target users and their needs in the selected content is important. This can be done through a questionnaire, a contextual inquiry, or similar approaches. The previous identified possible application components can also be included in the survey in order to evaluate their suitability.
4. **Select single components.** The further selection of components should be based on the gained insights on the target group and their potential feedback. In this work, components were introduced that are suited for certain program types and genres. Furthermore, additional application components could be collected by the identification of the target group, which states a contribution for the specific application and the collection in this work.
5. **Integration in prototypes.** The selected components should be integrated from early stages on in low fidelity porotypes of the second screen application. Not all components can be implemented adequately in low fidelity prototypes, but they are able to generate feedback nonetheless. Prototypes with a higher fidelity are typically better suited to demonstrate the benefits of the components.
6. **User testing.** In order to identify usability problems at early stages and to create applications that meet the needs of actual users, regular user testing in ideally all stages is important, also beyond the context of second screen application components. The heuristic checklist for second screen applications introduced later is a good addition to this process (cf. Figure Part III-1). The

steps of prototyping and testing typically go through several iterations until a completely satisfying result is achieved.

7. **Promotion of the application.** The promotion of the final application is included in this guide as several participants of studies carried out in this work were not aware of second screen applications and their benefits that already met their expectations. Therefore, promoting the created application is part of the process, also with the aim of raising public awareness of the benefits of second screens in general.

6.6 Summary of Application Components

Collection of the application components

In this chapter, components for second screen applications were introduced that create an additional value by satisfying an emerging user´s need related to the current content. These components were collected using a mixed methods approach consisting of a literature review and market analysis to identify the current state of the art, a cultural probe that provided authentic insights into actual second screen behavior, and an online survey to validate and assess the collected application components in relation to different program types and genres.

Validation of the application components

The presented components are categorized according to the previously introduced ISGCO classification for better overview and consist of 55 actual components in 16 subcategories. The online survey showed that there are large differences in the suitability of the individual components for certain program types and genres, which must be taken into account when selecting components. Finally, a seven-step guide was presented to facilitate the integration of the components into a user-centered design process.

7 Attention Guidance in Seconds Screen Applications

Multitasking while watching TV

Even without second screens, the use of television is often only a secondary matter: people eat, do housework, talk on the phone or to others while the television is switched on (Wolling & Kuhlmann, 2006, p. 386). New technologies, however, open up new possibilities of (parallel) activities for users, of which a broad spectrum was presented in the previous chapter.

The *attention* in such scenarios and the associated possible distraction from the first screen is one of the most frequently discussed aspects when using second screens[71]. This chapter presents two eye-tracking studies that were conducted with the help of second screen applications created to[72]:

Chapter aims

- capture the general *distribution* of attention,
- develop concepts for targeted *attention guidance*,
- *derive* general design recommendations in this context.

The results presented here are intended to help developers create new second screen applications where the different parts complement each other, rather than competing for the user's attention.

Chapter structure

The next chapter presents the current state of the art from the relevant literature (cf. Chapter 7.1) before the two studies on attentional behavior are described in more detail (cf. Chapter 7.2 & Chapter 7.3). Chapter 7.4 presents recommendations for attention guidance derived from literature and the studies, before finally a summary is given in Chapter 7.5.

[71] Abreu, Almeida, Silva et al. (2016); Almeida et al. (2015); Brown et al. (2014); Guo and Holmes (2016); Holmes et al. (2012); Kuhlmann and Wolling (2004); Neate et al. (2016), Neate et al. (2015a, 2015b), Shokrpour and Darnell (2017); Vatavu and Mancas (2014); Wolling and Kuhlmann (2006); Yeykelis et al. (2014)

[72] The results of Chapter 7 are published as: Lohmüller, V., Eiermann, P., Zeitlhöfler, P., & Wolff, C., (2019). Attention Guidance in Second Screen Applications [to appear]. In: Mensch und Computer 2019 – Tagungsband. New York, NY, USA: ACM. https://doi.org/10.1145/3340764.3340788

7.1 Attention Behavior at Second Screen Use

Lean back and lean forward media

The terms *lean back* and *lean forward* were coined by usability experts in the 1990s to describe rather alternative forms of media usage. On the one hand, television is used *passively* on a couch (lean back) and, on the other, the increasingly popular *active* personal computer and Internet access, where users usually sit on chairs (lean forward) (Stauff, 2015, p. 135). Even then, mixed forms already existed, such as game consoles, which combined both rather contradictory aspects. This clear separation, if it ever existed, has since become increasingly blurred, especially due to the enormous spread of mobile and Internet-enabled devices.

Second screening as field of tension

Consumer habits are changing with the technological devices surrounding televisions. Consumers are increasingly adopting a *lean forward* approach to the viewing experience by using connected devices as an extension of the program they are watching while *leaning back* or taking a variety of other positions on their couch or elsewhere (Abreu, Almeida, Silva et al., 2016, p. 901; Stauff, 2015, p. 140). The combination of these two rather contradictive experiences is characteristic for *second screening*, but also leads to an unresolved tension between to two devices in use (Brown et al., 2014; Johnen & Stark, 2015; Silva et al., 2015; Stauff, 2015; Vanattenhoven & Geerts, 2017). This tension is gaining relevance due to the growing access to second screen devices in recent years, which increases the challenges in the area of divided attention and the importance of finding solutions, able to balance the user's attention between two or more sources (Abreu, Almeida, Silva et al., 2016, p. 901).

Increasing media multitasking activity

This media multitasking is anything but new, first studies on the rarely isolated use of radio date back to 1935 (Cantril & Allport, 1935), but the spread of mobile devices that make it possible to produce and consume media content simultaneously has led to an increased multi-tasking rate among all age groups in recent years (Lowenstein-Barkai & Lev-On, 2018, p. 2).

Substituting or complementing

In most cases, the additional second screen does not attempt to replace the older medium but rather to complement it. However, this depends on the specific scenario and the design of the application so as not to interfere with the viewing

experience and thus allow a deeper understanding and involvement of the current content (Lowenstein-Barkai & Lev-On, 2018, p. 1).

Previous studies and delimitation

Previous studies in this direction have examined individual aspects of attention on second screens, such as the design of notifications on first (Weber, Mayer, Voit, Ventura Fierro, & Henze, 2016) and second screens (Abreu, Almeida, Silva et al., 2016; Almeida et al., 2015), possible reasons for multitasking (Wolling & Kuhlmann, 2006), the evaluation of different multi-screen layouts (Vatavu & Mancas, 2014), or the general distribution of attention (Holmes et al., 2012).

The two studies presented below were developed to take into account aspects from the relevant literature and to gain further insights for the user-centered design of second screen applications. Figure 7-1 gives an overview of the methodology used to generate insights on the distribution of attention and design recommendations. The study design was divided into two studies in order to keep the survey variables manageable and to be able to apply the findings from the first directly to the second study.

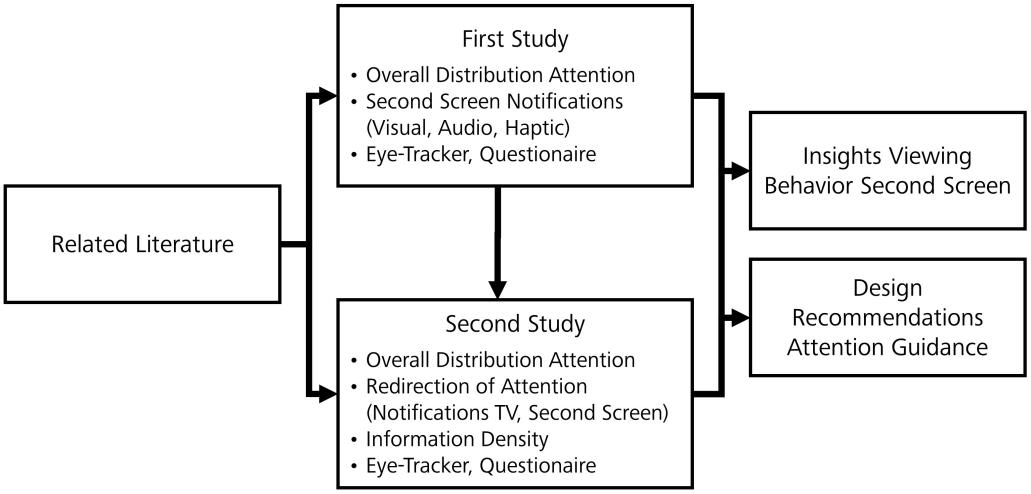

Figure 7-1: Methodology used to generate insights for attention distribution and design recommendations.

7.2 Directing Attention to the Second Screen

The first study examined the attention directed towards the second screen in relation to different notifications modalities and the overall distribution of attention

during a second screen usage. Previous studies in this area have examined individual related aspects, which are discussed below and highlighted with differences to the approach used here.

Notifications in previous studies

Abreu, Almeida, Silva et al. (2016) conducted a laboratory study in which visual, audio, and haptic notifications indicated new information on the second screen, paired with additional visual notifications on the first screen. The different types of notifications were triggered individually and differently combined in random order and had to be acknowledged manually by pressing a button. The additional information consisted of an image and a short text section related to the televised content, such as the appearance of a character. At the end, the participants were asked to fill out a small questionnaire to collect information regarding the experience they just had. Similar to the notification modality test, the intervals between notifications (10, 30, and 60 seconds) were surveyed.

Previous notification drawbacks

The contribution in this work to the approach of Abreu, Almeida, Silva et al. (2016) is the integration of an eye-tracker for more detailed study of attention during the second screen usage and the different notifications. This combination of objective eye-tracker and subjective user data led to a more comprehensive evaluation of the selection of second screen notifications. In contrast to pressing a button to acknowledge a notification, which can influence the participant's immersion, this work automatically evaluated the notifications with the eye-tracker used. The findings regarding the time interval of the notifications were taken from Abreu, Almeida, Silva et al. (2016), since an eye-tracker evaluation regarding this aspect would presumably not have yielded any new findings.

Attention survey in other studies

Brown et al. (2014) and Holmes et al. (2012) conducted eye-tracking studies in laboratories designed to mimic a living-room at home with the aim of better understanding the interaction with both the first and second screen. Holmes et al. (2012) used an application with audio fingerprints to synchronize the second to the first screen and displayed additional information on a fixed position tablet without additional notifications. Brown et al. (2014) used stationary eye-trackers and additional information on a fixed tablet without notifications to indicate new

content synchronized in time, to survey the overall attention during second screen usage.

Previous attention survey drawbacks

Brown et al. (2014, p. 668) used two stationary eye-trackers, one for each screen, which allows a different level of evaluation compared to a mobile eye-tracker and requires the second screen to remain fixed at the same position, as in Holmes et al. (2012) study, and thereby restricting the natural second screen behavior. All applications discussed in this section are not directly and functionally connected to the first screen, in contrast to the second screen application used in this work. The direct connection and the associated control with the second screen represents a different level of interactivity and experience in comparison with unconnected applications (Bernhaupt et al., 2013, 6). Furthermore, in previous literature, either the general distribution or the targeted directing of attention has been examined and not both together as in this work. A more detailed description of the test setup used is given in the next section.

7.2.1 Methodology Evaluating Attention towards the Second Screen

The first study on attention behavior in second screen applications was designed to investigate the following aspects:

Goals

- Total distribution of visual attention with an interactive second screen application.
- The type of notification (*visual*, *audio*, or *haptic*) is best suited to direct the user's attention to the second screen.

Second screen application

For this purpose, a version of *Audi MediaTV* (cf. Chapter 5.2) was adapted to present information related to the current content, such as offers for the cars currently on display on the first screen. This information was displayed at the top of the current screen for a period of time to allow further use of the application. A complete list of the additional information and the questionnaires used in the study can be found in Appendix D.1. The order of the notifications was evenly alternated, ensuring that the sequence of appearance did not affect the data collected. The various notification modalities have been tested individually to better assess their suitability.

Test setup

The study was carried out in a laboratory designed as a living room with a sofa, snacks, and a television screen (55 in., 4K) with the aim of ensuring that participants behave as naturally as possible[73]. The participants first completed a questionnaire from which their demographic data and previous experience with second screen applications were collected. After calibrating the mobile eye-tracker, the participants were asked to establish a connection between the first and second screen, and select and view three specific videos: an advertising spot, a video about the opening of an automotive plant in Mexico, and an advertising presence of football players, at which each two notifications were triggered. The videos have been selected to reflect the widest possible range of different content within the used second screen application. The additional information and notifications were not communicated to the participants in advance and appeared to all participants at the same time during the videos in order to avoid possible influences on the data, differentiating only between visual, audio, and haptic notifications. The mobile eye-tracker measured the response time to the different notifications and the overall viewing behavior during the study. After watching the three videos the participants were asked to submit their opinions on the given notifications in a final questionnaire consisting of 5-point Likert scales (1 = totally disagree, 5 = totally agree). In the evaluation of these Likert scales, the results were summarized with one and two as *disagree*, three as *neutral*, and four and five as *agree*. The combination of these subjective user and objective eye-tracking data provided a comprehensive insight into the questions under investigation, for which the results are presented in the next section.

7.2.2 Result First Eye-Tracking Study

Participants

The study on the direction of attention towards the second screen was completed by 30 participants (15 female, 15 male), with an average age of 23.2 years and a

[73] The conduct and evaluation of the study was part of the bachelor thesis of Philip Eiermann, which was supervised by the author.

range of eight years, and represents a rather homogenous group. The results regarding the distribution of attention during the usage of an interactive second screen application are presented in the following subsection.

7.2.2.1 *Visual Attention Distribution*

Surveyed distribution of attention

The overall distribution of visual attention was captured with a mobile eye-tracker and revealed that the majority of attention was on the first screen with 82.6% and 16.4% of the gaze time was directed towards the second screen. This distribution is shown in Table 7-1.

	Total Time (s)	Average (s)	SD	Percentage
First Screen	7312.3	243.7	44.4	82.6%
Second Screen	1449.8	48.3	14.7	16.4%
Other	88.7	2.9	4.1	1%

Table 7-1: Overall distribution of visual attention in the first eye-tracking study.

Comparison of results with literature

These results were measured when the first screen was controlled by the second screen and various notifications repeatedly drew the attention to it. Nevertheless, the first screen focus area (M = 243.7 s, SD = 44.4) had a considerably longer average attention duration than the second screen (M = 48.3 s, SD = 14.7). This result matches that of Brown et al. (2014) (first screen 76.5%, second screen 16.9%) and Holmes et al. (2012) (first screen 62.9%, second screen 29.85%) who used a similar experimental setup but did not provide notifications for new information on the second screen. This relation is also influenced by the type and amount of additional information; in this study, the given information texts were rather short and available for a rather short period of time, which could explain the rather low attention level on the second screen. The next section presents the results on efficiency of different modal notifications to draw attention to the second screen.

7.2.2.2 *Suitability of Notifications on the Second Screen*

Eye-tracking data

The first aspect regarding the efficiency of notifications on the second screen was the quantitative data collected by the eye-tracker, namely whether the information was perceived and the time needed for perception. With regard to these criteria, *auditory* and *haptic* notifications were equally efficient in the study with an average reaction time of 1.5 and 1.4 seconds and very few missing responses, three and one of a total of 180 notifications. *Visual* notifications, on the other hand, had a noticeably slower average response time (4.3 s) and a considerably higher number of missed responses (20%). If a participant was already looking at the second screen at the time of the notification, no change of view could be detected, which is why these notifications were not included in the evaluation of the data. These results are shown in Table 7-2. The data collected indicate that auditory and haptic notifications draw attention to the second screen much faster and more reliably than purely visual notifications.

Notification (n = 180)	Reaction Time (s) Ø	SD	No Reaction	No Change in View
Auditory	1.5	0.7	3	2
Haptic	1.4	1.1	1	1
Visual	4.3	4.2	36	2

Table 7-2: Reaction time, missing reactions, and not changed views for the individual notifications.

Participant data

In addition to the objective eye-tracker data, the participants were asked about their personal perception of the different notification types. *Auditory* notifications were considered disruptive by 30%, *haptic* notifications by 10%, and *visual* notifications by 6.6% of the participants. As with the eye-tracker data, participants reported that *auditory* and *haptic* notifications strongly attract attention as opposed to *visual* notifications, which were also not considered as an improvement to the TV experience. Figure 7-2 displays the results of the questionnaire completed after the test.

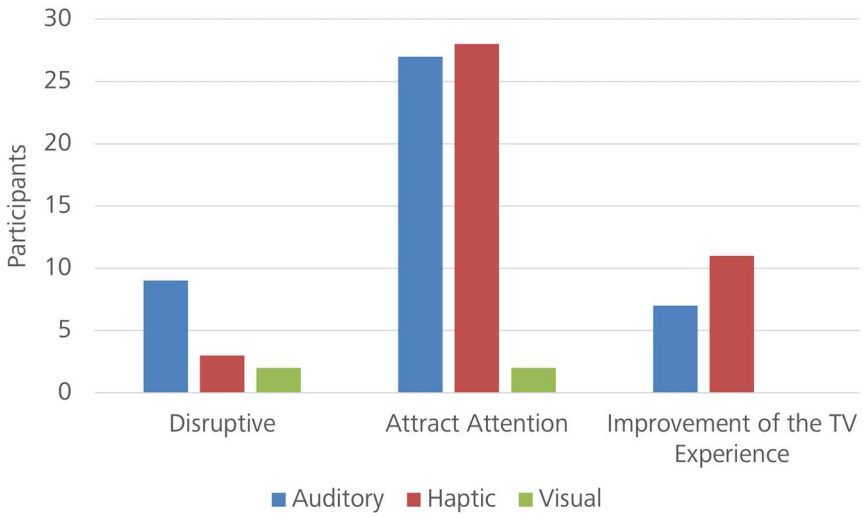

Figure 7-2: Evaluation of the different types of notifications by the participants.

Combination of results

In a combination of the collected qualitative user and quantitative eye-tracker data, *haptic* notifications were rated as the most suitable overall, with *auditory* notifications also strongly drawing attention. These notifications are well suited for important and time-relevant information, but can be perceived as disruptive. Due to their inconspicuous nature, visual notifications are better suited for background information. Whether notifications are perceived as disruptive also depends on the current context and how often they are triggered (Abreu, Almeida, Silva et al., 2016). In the study presented here, the participants watched three short car-related videos (1 – 3 minutes). Content with a higher level of immersion, such as movies, more inconspicuous notifications are presumably more appropriate. The amount of information to which the notification refers must also be adapted to the current content, the so-called *curation of content*. This aspect was also investigated in the second study, which is presented in the next chapter with two concepts for drawing attention back to the first screen.

7.3 A Holistic Attention Concept for Second Screen Applications

In the second study on second screen attention guidance, a more holistic approach was developed, implemented, and evaluated, including a concept for redirecting attention to the first screen and the shared display of information. These concepts are also represented in the relevant literature, which are outlined in the following with the central differences to the approach pursued here.

Notifications first screen

One part relates to the overall design of notifications for directing attention. The previous chapter (cf. Chapter 7.2) examined the direction of attention towards the second screen and addressed the relevant literature in the process. Weber et al. (2016) derived design guidelines for notifications exclusively on smart TVs by exploring design solutions with focus groups and assessing the alternatives by an online survey and a lab study. The findings were obtained without regard to a possible second screen, which is considered in this section and additionally examined with an eye-tracker in order to generate deeper insights on the holistic control of attention.

Information density

Another aspect that needs to be considered is the complexity and amount of information given, referred to here as *information density*. Neate et al. (2016) conducted a study on this matter by offering different levels of information complexity, surveying the gaze time and the participants´ impressions in a questionnaire and thereby identifying *textual* information as a key factor influencing the dual-screen experience. In a second study, they investigated the influence of adjustable and curated content. This curation of complexity, the adaptation of the complexity of the information on the second screen to that of the first screen, was also identified as a key factor and is thus incorporated in the design of the study conducted here.

Previous attention survey drawbacks

The results of Neate et al. (2016) are mainly based on gaze time, which was captured manually in the studies by annotating the captured video material. In the approach used here, a mobile eye-tracker was used to enable an even more accurate evaluation. In addition, notifications of new content were treated only marginally, which plays a more central role in the study carried out here. The following section describes the applied methodology for the study.

7.3.1 Methodology Evaluation of a Holistic Attention Concept

The second eye-tracking study was developed to investigate the following objectives[74]:

- Total distribution of visual attention with an interactive second screen application.
- Investigation of attention redirection via first and second screen.
- Assessment of a divided and one-sided display of information on the first and second screen.

Second study overview

The insights from literature and results of the first study were considered in the focus group, the prototype, and the study design. The collected data again consisted of *objective* eye-tracking and *subjective* user data, an overview of the approach followed in the second study is displayed in Figure 7-3.

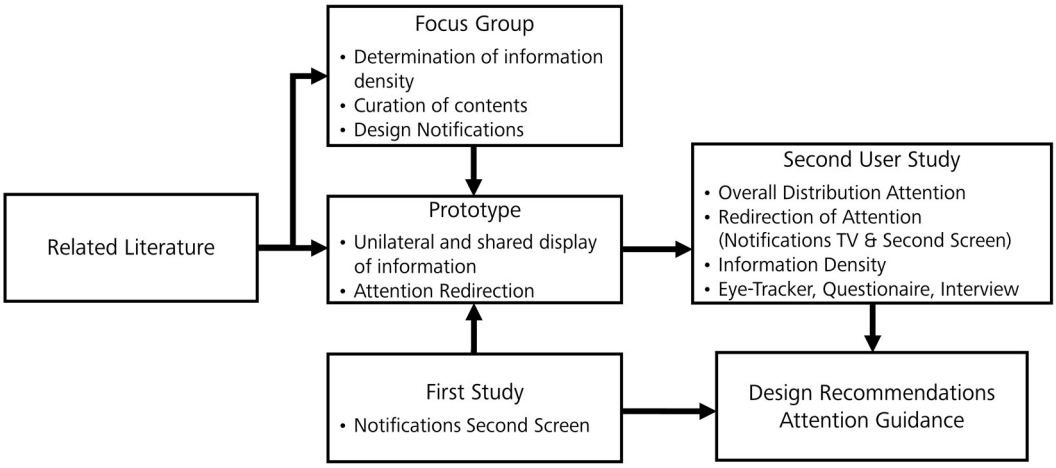

Figure 7-3: Approach to generate insights for attention distribution and design recommendations in the second study.

Focus group

The focus group consisted of five participants (2 female, 3 male) who evaluated additional information in various forms in a 60-minute discussion of the topic. After a short introduction, the selected 12-minute video of the later test was shown to the focus group, followed by an assessment of previously generated additional information. The additional information consisted of three different

[74] The execution of the second study and the implementation of the associated application was part of Peter Zeitlhöfler's bachelor thesis, which was supervised by the author.

versions, which were modelled according to Neate et al. (2016): detailed continuous text, key points, and a shortened version of the key points with less information. These aspects were evaluated in terms of complexity and ease of use in the context of the second screen application. Subsequently, the documentary was presented again in individual partial sequences in order to discuss the curation of the contents, e.g. suitable times for displaying the additional information either on the first or on the second screen. The last point of discussion was about the design of the additional information and the various modalities in order to redirect the attention of the user to reach the TV.

Prototype

A second screen application consisting of two parts was developed as prototype, a mobile part for *Android* and the first screen part for *FireTV*. The *2ndS SDK* was used for the connection setup and communication between the two parts (cf. Chapter 4).

Design of additional information

The created system was able to display additional information on the first and second screen at certain times. The *position* of the additional information on the first screen was chosen by the participants to determine the preferred placement and the *size* was set to ensure good legibility of the information. The additional information on the first screen was displayed for ten seconds and on the second screen until the next content was available.

Notifications

In the time coordination of the additional information, the results of Almeida et al. (2015) that new additional information is best displayed at intervals of 30 seconds to one minute and the results of the focus group with the coordinated times were taken into account. As result, the time intervals of the additional information were between 21 and 157 seconds (mean value 57.3 seconds). For the notification of new content, the second screen gave *haptic* feedback (700ms), which was identified as the best solution in literature (Almeida et al., 2015) and the previous study.

Surveyed concepts in the prototype

The prototype provided two versions for the display of the additional information, which represents one of the aspects investigated in the study: the display of information only on the second screen and the divided display on both parts

of the application. Furthermore, the redirection of attention was investigated using two different approaches: a hint on the second screen to look at the first again, triggered by a shorter vibration (200ms), and an acoustic signal on the first screen. A redirection by means of a visual notification on the first screen did not seem to make sense, as this can only be detected if the user is already looking at it, which is why an auditory signal was selected. The different redirection concepts were triggered at changes of topic and before the narrator started talking. Figure 7-4 gives an overview of the one-sided and divided concepts.

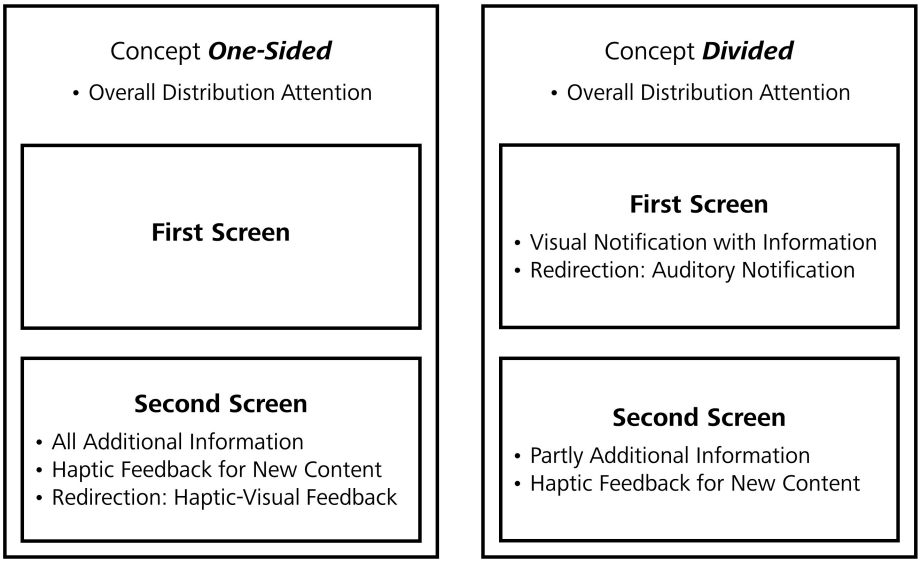

Figure 7-4: O*ne-sided* and *divided* concepts of redirection.

Test setting

The study was carried out in a laboratory modeled after a living room in order to create as natural an environment as possible. The video was shown on a *Samsung* Smart TV using an *Amazon FireTV* (Generation 3), and the second screen was a smartphone *LG G5*.

Test procedure

To test the different approaches displaying additional information, the participants were divided into two groups: one where the information is displayed only on the second screen and the other where information is displayed on both parts of the application. The different approaches of redirecting attention were also integrated into these groups by providing all information and the redirection via the second screen on the one hand, and using a divided concept with first screen on the other. At the beginning of the test, the demographic data of the

participants were collected in a questionnaire, after they had been equipped with an eye-tracker and received a short introduction to the functionality of the second screen application. Before the actual test, in which a twelve-minute documentary (Tidmarsch & Fothergill, 2008) with additional information was shown, the participants were asked to select a position for the notifications on the first screen. The additional information consisted mainly of textual information and images describing animals and locations obtained from *Wikipedia* and adapted by the focus group to the current content. After the test, participants were asked in qualitative questionnaires about their ability to follow the content and their preferences for redirection before finally filling in in the *system usability scale* (SUS) questionnaire (Brooke, 1996) and being interviewed about their experience with the different concepts. In the evaluation of the Likert scales, the results were summarized with one & two as *disagree*, three as *neutral*, and four & five as *agree*. The complete questionnaires and additional information can be found in Appendix D.2.

7.3.2 Results Second Study

Participants

The second study was completed by 20 participants (8 female, 12 male), with an average age of 26.6 years and a range of nine years. The participants were divided into two groups (each four female, six male), that either completed the version with all information and redirection on the second screen or the concept with a divided display, as described in the previous chapter.

7.3.2.1 *Visual Attention Distribution Second Study*

Problems collecting eye-tracking data

During the annotation of the eye-tracker data, it became clear that some glances could not be captured by the camera of the mobile eye-tracker at strong eye movements upwards or downwards. This was mainly because some participants put their mobile phones on their laps and made only slight movements with their heads when changing their eyes, which led to extreme eye movements and led to difficulties at the evaluation. For this reason, only clearly recognizable glances were evaluated for the distribution of attention between television and

smartphone. This distribution is shown in Table 7-3 and distinguishes the group with the one-sided and divided redirection and display of information.

	Time (s)	SD	Percentage
One-Sided			
First Screen	4800	79.8	66.4%
Second Screen	960	20.9	13.2%
Divided			
First Screen	5143	44.3	71.1%
Second Screen	795	31.1	11.0%

Table 7-3: Collected distribution of attention between the one-sided and divided redirection and display of information.

Results eye-tracking data

The eye-tracker data indicates that with the divided concept more attention is set on the first screen (66.4% & 71.1%), but the difference between the groups in this study is not meaningful enough to indicate a clear difference in attention duration between the two approaches. In the distribution of attention between the first and second screen, on the other hand, the first screen had considerably more attention durations in both groups than the second. These results are consistent with those of the first study and related literature described in Chapter 7.2.2.1.

7.3.2.2 *Redirection of Attention Towards the First Screen*

In addition to the survey of the general attention when using a second screen application, different concepts for redirecting attention towards the first screen were investigated. These concepts consisted of an auditory notification on the first screen or haptic feedback on second screen with an indication to look at the first screen again. On the one hand, the eye-tracker was used to record the changes in view in the different notification types, as shown in Figure 7-5, and on the other hand, the subjective opinions of the participants were collected in a survey after the test (cf. Chapter 7.3.1).

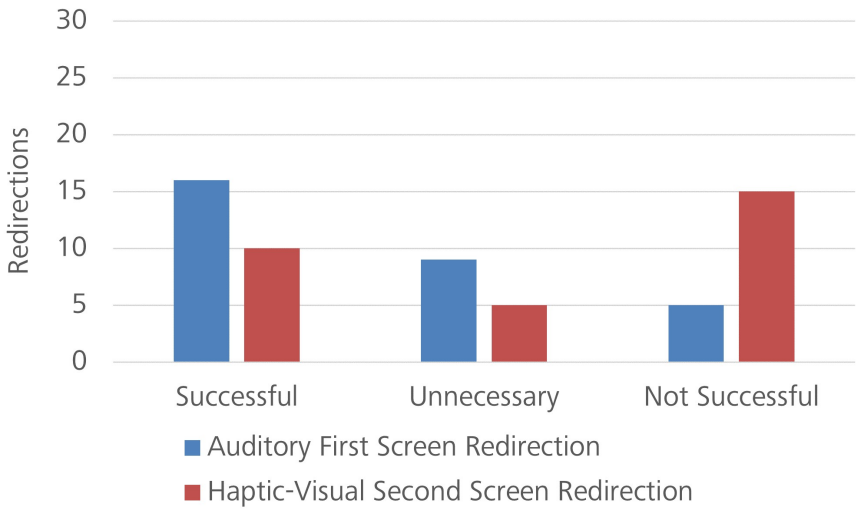

Figure 7-5: Recorded changes in view with the eye-tracker between the different redirection concepts.

Evaluation redirection in eye-tracker data

Out of the 30 redirections with the concept of auditory first screen redirection, 16 were successful, nine were unnecessary because the focus was already set on the first screen, and five were without reaction. With the haptic-visual redirection on second screen were ten successful, five unnecessary, 15 unsuccessful. In many cases, the unsuccessful redirection of attention had even an opposing effect: the participants drew their attention from the first to the second screen because they thought that new information was available. To avoid this behavior, different types of haptic feedback were chosen, longer vibration (700ms) for new information and a short vibration (200ms) for redirecting the attention, but the whole concept of redirection with the help of the second screen proved counterproductive.

Subjective evaluation of redirection by participants

This concept was also evaluated as counterintuitive in the subjective data of the participants, as shown in Figure 7-6. Both, the auditory and the haptic-visual redirection were assessed as noticeable, but the latter was clearly considered unsuitable for redirection by the participants.

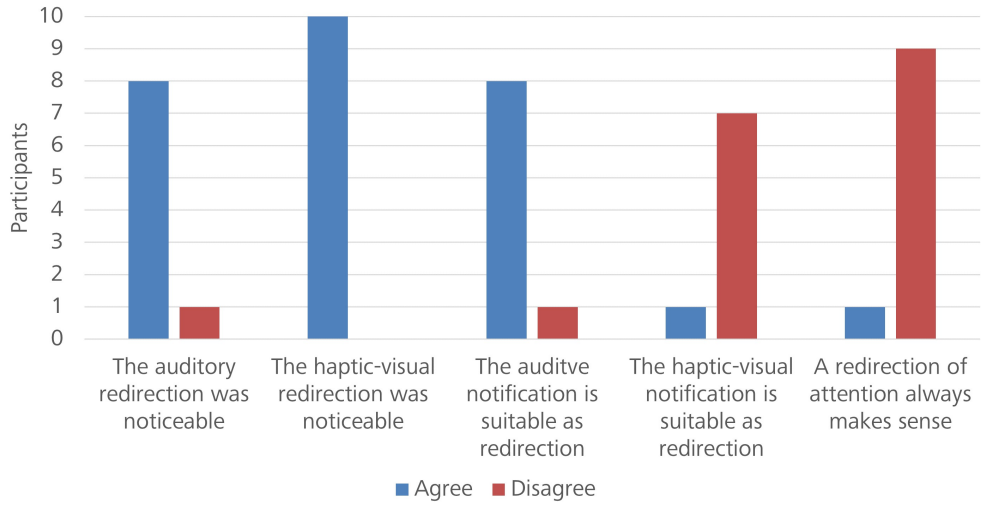

Figure 7-6: Subjective assessment of participants regarding the auditory and haptic-visual redirecting concepts.

Combination of collected data

From the combination of the subjective participants and objective eye-tracker data, a redirection via the second screen was evaluated as impractical. The intention to redirect users to the first screen using the second screen proved to be counterproductive and could only work if it could be ensured that the user is looking on the second screen, which currently states a technical challenge.

Redirection conclusion

The general concept of redirecting attention towards the first screen was not considered useful in all contexts, but part of the qualitative feedback showed that it may be useful to point out topic changes, which is consistent with the results of the focus group. If a redirection is used in a second screen application, it should be possible to adjust the settings to the individual needs of the current user, since these can be perceived as disruptive depending on preference and context. The further results on how to design attention redirection are presented in Chapter 7.4. In the next section, the results of the one-sided and divided presentation of information are described.

7.3.2.3 *One-sided and divided display of information*

Evaluation of additional information

The evaluation of the divided and one-sided display of additional information showed that the group of the divided display had considerably fewer problems consuming the additional information and at the same time following the content of the first screen. Additionally, the amount of information given was considered

more balanced, although the same amount was given in both groups. Figure 7-7 visualizes these aspects.

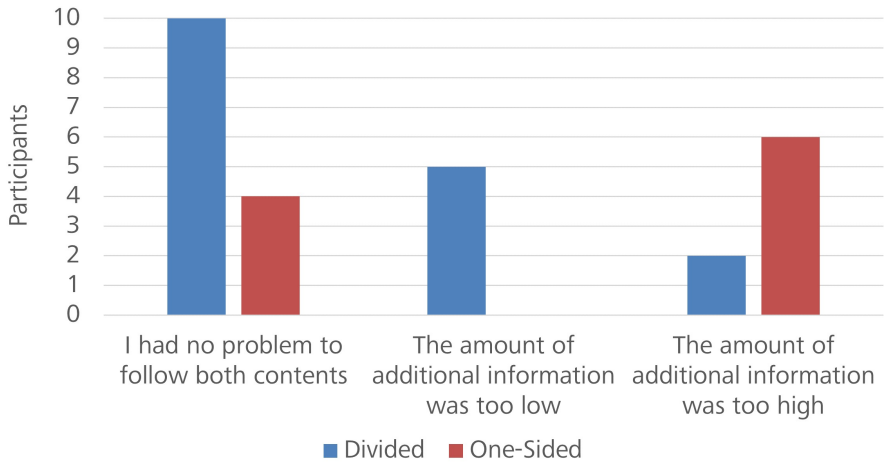

Figure 7-7: Assessment of the additional information in the divided and one-sided concept.

Less textual information is preferred

In the qualitative follow-up survey, all participants in both groups indicated that they preferred the additional information in key points rather than in continuous text. In addition, the curation of the content was considered important. These findings regarding a lower information density are consistent with those of the focus group and the relevant literature (Neate et al., 2016).

Position of information

When selecting the position of the additional information on the first screen, all participants in the group with the distributed information (n=10) opted independently for a display in the upper right corner, which agrees with findings from literature (Weber et al., 2016). The next section summarizes the insights gained regarding attention behavior and the associated design recommendations for second screen applications.

7.4 Guidelines for the Direction of Attention in Second Screen Applications

This section presents findings regarding the direction of attention with second screen applications, gained by two studies conducted in this context described in the previous chapters, and from insights extracted from the relevant literature. The general direction of attention in second screen applications is strongly de-

pendent on the context, but there are some recommendations that should be considered generally, alongside those for the second and first screen, which are presented below:

General Recommendations:

- **First screen is first:** Both studies as well as the literature (Brown et al., 2014, p. 670; Holmes et al., 2012, p. 399) confirm that the main part of attention is set on the first screen (cf. Chapter 7.2.2.1 & Chapter 7.3.2.1), which should be considered designing second screen applications.
- **Consistent design:** Just as the general design of second screen application, the design of the notifications and additional information in particular should be uniform in order to facilitate the perception as a coherent system. However, different notification tones should be used on the first and second screens to avoid possible confusion.
- **Timing**: Notifications should be made at an interval of at least 30 seconds to 1 minute to avoid fatiguing effects and to allow better management of attention (Abreu, Almeida, Silva et al., 2016, p. 909).
- **General customizability:** Any notifications should be deactivatable in the application settings, as they might be perceived as disruptive depending on context and preference of the user.
- **Duplication of information:** In an application with a tight coupling between the two parts, the double display of information may be useful as it may reduce the number changes of view between the screens. Direct feedback on both screens during input is important to strengthen the sense of cohesion and to facilitate the overview of the distributed system.
- **Curation of content:** The coordination of the notification and the related information density with the current content of the first screen was considered important in the studies presented here and in the literature (Neate et al., 2016, p. 481). Overall, short key points and images are best for additional information and should not be displayed if the complexity on the first screen is currently high. However, this coordination of the contents was assessed as very time-consuming.

Second Screen Notification:

- **Drawing attention towards the second screen**: *Haptic* notifications are best suited for important or time-relevant notifications. *Auditive* and *haptic* notifications can be perceived as disruptive and should be used accordingly. *Visual* notifications are suitable for background and not time-relevant information.
- **Notification announcement:** A display indicating the time until the next notification on the second screen was considered useful by participants (Geerts et al., 2014, p. 100).
- **Availability of previous notifications:** Notifications already displayed should be available, for example in a list (Neate et al., 2016) or with thumbnails (Abreu, Almeida, Silva et al., 2016).

First Screen Recommendations:

- **First screen notifications**: Notification were found to be desirable with the right design: important changes on the first screen can be indicated with subtle *auditory* notifications. The position of notifications on the first screen is preferable the top right corner, but should also be adjustable together with size, opacity, display duration, and text length (Weber et al., 2016, Design Guidelines). In addition, the user should be able to adjust the notification tone and volume and deactivate the notifications.
- **Redirection second screen**: A redirection to the first screen using the second screen was found to be counterproductive and counterintuitive.
- **Distribution of information**: The distribution of additional information on first and second screen makes it easier to consume them and at the same time follow the content of the first screen. Additionally, the amount of given information is considered more balanced.

The results of the two studies carried out on attention behavior with second screens were also used in the design guidelines presented in the following chapter, after a brief summary of this chapter is given below.

7.5 Summary Attention Guidance

This chapter presents findings from two eye-tracking studies on the direction of attention with second screen applications. The studies were designed incorporating findings from relevant literature to produce more profound insights on attention behavior and notification efficiency. Both studies confirm with the help of a mobile eye tacker that most of attention during second screen use is set on the first screen, which is in line with related findings (Brown et al., 2014, p. 670; Holmes et al., 2012, p. 399).

Results first study

The first study shows by means of 30 participants in a mixture of objective eye-tracking data and subjective user data that *haptic* notifications are best suited to draw attention to the second screen. It also was shown that haptic and auditory notifications can be perceived as disruptive and therefore visual notifications are well suited for background and non-time relevant information.

Results second study

The second study shows that the distribution of additional information on the second and first screen facilitates its consumption and the following of the current content. A concept of redirecting attention towards the first screen using the second screen was found to be inappropriate; instead, visual or, for important changes auditory notifications on the first screen are suitable. The adaptation of the density of the additional information to the content of the first screen was also found to be important, but also time consuming.

Summing up, the second screen is able to play a complementary role - instead of a merely supplementary one, if it is properly designed. More studies are needed to determine this design, e.g. on the influence of different content, such as movies or news, on the type of notification. The next chapter presents more detailed guidelines for the design of second screen applications, which also take into account the findings of the studies presented here.

8 Guidelines for Second Screen Applications

To be considered as usable, second screen applications must be consistent and behave as expected by users. Design guidelines are a common approach to ensure these qualities when it comes to designing software. There are currently several design recommendations, guidelines, and patterns available for second screen applications. The given recommendations from these different sources often contradict each other, which leads to applications with inconsistent interaction concepts. To address this problem, this chapter introduces abstracted design guidelines on basis of the available recommendations and a user study that assess the different concepts.

Chapter structure

Chapter 8.1 gives an overview on the origin and aims of guidelines; Chapter 8.2 presents the procedure applied to develop the design guideline for second screen application, before the results are presented in Chapter 8.3, and finally a brief summary is given in Chapter 8.4.

8.1 Guidelines in Software Development

Guidelines

The existence of guidelines for the design of media goes back hundreds of years before the invention of mobile applications and the internet. Especially in the field of graphic and text design, there are established rules that are still valid today (Malaka et al., 2009, p. 392). This also applies to one of the first studies on second screen applications (Robertson et al., 1996), which also proposes design guidelines based on their experience, some of which still apply today. Today there are countless guidelines for the design of digital products such as websites, mobile applications, or more specific topics such as second screen applications.

Differentiation guidelines & style guides

These guidelines have different levels of specificity, ranging from general design laws that apply to all media types, guidelines for individual software platforms, to recommendations that apply to individual applications only. In most cases, the more specific guidelines must take into account the more general aspects in this context. The exact differentiation of terms for these *design recommendations* often becomes blurred. In this work, *design guidelines* are understood as

concrete visualized instructions that, in contrast to *style guides*, also contain whole processes.

Consistency

Second screen applications represent a special field of tension for design recommendations, because one application can encompass several platforms. This means that different guidelines or style guides can apply to first and second screen, which is problematic for the *consistency* within the application. Malaka et al. (2009, p. 382ff.) see *consistency* as one of the most important prerequisites for the usability of software applications. Consistency in digital products describes how different design features such as metaphors, icons, colors, and sounds are used in a uniform manner, distinguishing between *internal* and *external* consistency.

Internal consistency

Internal consistency refers to the uniformity *within* an application, for example, the use of graphic features that can always be similar from screen to screen. This includes not only the graphic design of applications, but also areas such as interaction design. Internal consistency is much easier to ensure than external consistency, since designers within an application are largely free to choose elements uniformly, even if often platform-specific style guides from manufacturers have to be taken into account.

External consistency

External consistency, on the other hand, refers to uniformity across different applications. For example, it is expected for most Windows programs to have a button at the top right that is marked with an "X" to close the window. This consistency is much more difficult to achieve than internal consistency, which is also due to the coexistence of many current solutions. These existing standards and user expectations must be adhered to, in order to ensure external consistency.

Guidelines for second screen applications

In some cases, no solution can be designed that meets all expectations, because existing established solutions and design recommendations are inconsistent or contradict each other. Therefore, existing guidelines for second screen applications and available solutions were evaluated and the resulting concepts were examined in user tests, in order to provide a reasoned recommendation in the form of design guidelines for second screen applications.

8.2 Procedure for the Development of the Guidelines

Problems of existing design recommendations

One of the problems in the development of second screen applications is the coexistence of several design recommendations from manufacturers and interaction concepts in established solutions that are inconsistent and sometimes contradictory. Often, developers cannot design applications that are consistent with all expectations, and must therefore decide what user expectations are typical in certain scenarios. In second screen applications, this problem is aggravated by the different platforms and the associated guidelines to which first and second screen may belong.

Methodology

In order to provide a well-reasoned recommendation in the form of concrete design guidelines, the available guidelines provided by the manufacturers *Amazon*[75], *Google*[76], and *Samsung*[77] were examined with regard to their similarities and compared with established solutions, namely *Amazon Prime Video*, *Netflix*, and *YouTube*. These second screen applications were selected for their similarity in functionality, as they are all media library applications with a wide distribution, each ranging between 50 million and one billion downloads on the mobile operating system *Android* alone (Amazon Mobile LLC, 2018; Google LLC, 2018; Netflix, 2018). The different concepts were compared in a functional matrix (cf. Appendix E.1) in order to create an overview of currently established concepts, from which identified differences were assessed in a user test. Figure 8-1 shows the methodology applied for the development of the design recommendations from existing guidelines and established applications[78].

[75] https://developer.amazon.com/de/docs/fling/designing-amazon-fling-ux.html
[76] https://developers.google.com/cast/docs/ux_guidelines
[77] https://developer.samsung.com/tv/design/smart-view-sdk/
[78] The conduct and evaluation of the study was part of the bachelor thesis of Marcus Beck, which was supervised by the author.

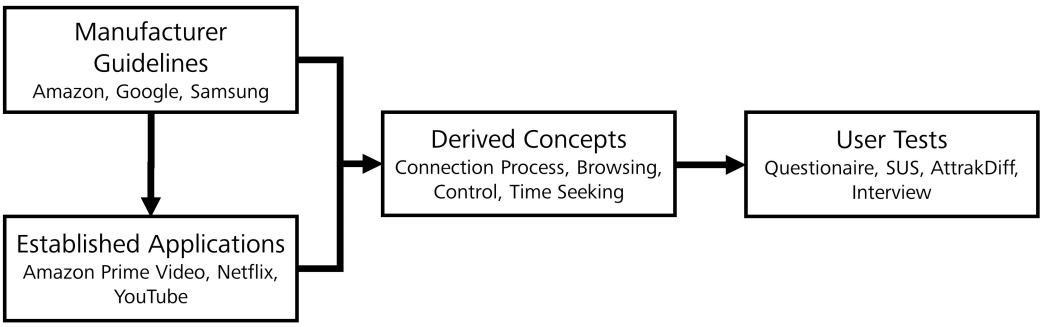

Figure 8-1: Approach for reasoned design recommendations from existing guidelines by manufacturers and established applications.

8.2.1 Second Screen Guidelines by Manufactures

Problem of different available guidelines

There are guidelines from the different manufacturers available for the development of second screen applications such as *Amazon FireTV*[79], *Android TV*[80], and *Samsung Tizen*[81]. These guidelines are part of the associated connectivity SDKs and must be applied to meet the criteria for publication in the relevant app stores. If a second screen application supports multiple platforms, the consistency of the resulting application may be at risk if different design recommendations are made by the different guidelines. The most important differences and intersections between the analyzed manufacturers´ guidelines are presented in the following. The results described here are limited to the most basic processes of second screen applications, the *connection process* and the *control* of the first via the second screen.

Connection Process

Similar connection process in guidelines

The connection process is almost identical between the different surveyed guidelines. The availability and status of a second screen connection is indicated by a *cast button* visible from all screens of the application. This cast button is positioned in the upper right corner in all cases and share the same icon between *Google* and *Samsung*. Pressing the cast button displays a list of available devices, which closes

[79] https://developer.amazon.com/de/docs/fling/designing-amazon-fling-ux.html
[80] https://developers.google.com/cast/docs/ux_guidelines
[81] https://developer.samsung.com/tv/design/smart-view-sdk/

automatically when a target device is selected. A successful connection is indicated by a colored version of the cast button. *Google* and *Samsung* also progressively animate the waves in the cast button during the connection process to indicate progress. The connection can be established either before or after selecting content on the second screen. Positive feedback about a successful connection from the first screen was not recommended in the guidelines explicitly. The similarity in the connection process between the different guidelines is shown in Figure 8-2, which displays the first step in the connection of a first screen.

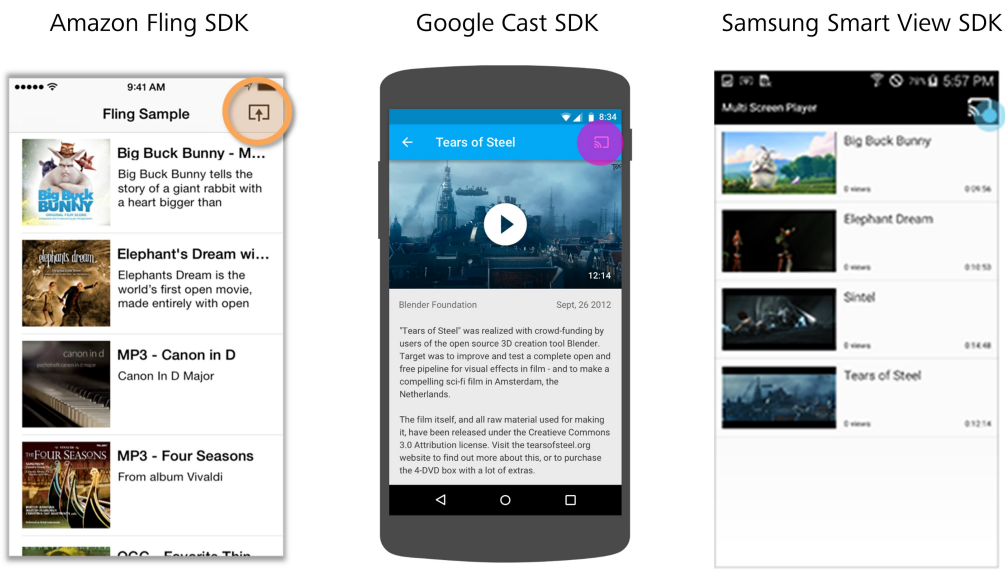

Figure 8-2: Cast button in manufacturer guidelines showing available connections.

Control

Control bar

Besides the connection process, the control of the first screen via a second screen is one of the most basic concepts for this type of application. Thereby more differences were found in the analyzed guidelines than in the previous, almost identical, connection processes. *Amazon* and *Google* recommend the display of a permanent visible *control bar* on the bottom of every screen as soon as a connection is established and content is played, which is displayed in Figure 8-3. This control bar eases the browsing within the application and allows direct control over the first screen content at any time. *Google* additionally recommends the display of lock screen displays to make the control of the first screen more accessible.

General controls

The general control of the first screen content via the second screen is very similar between all the recommendations. These controls include besides *play* and *pause*, *fast forward*, *rewind*, a *timeline*, and at *Amazon* and *Samsung stop*. These controls are available on an extra screen with images associated to the current content on the first screen.

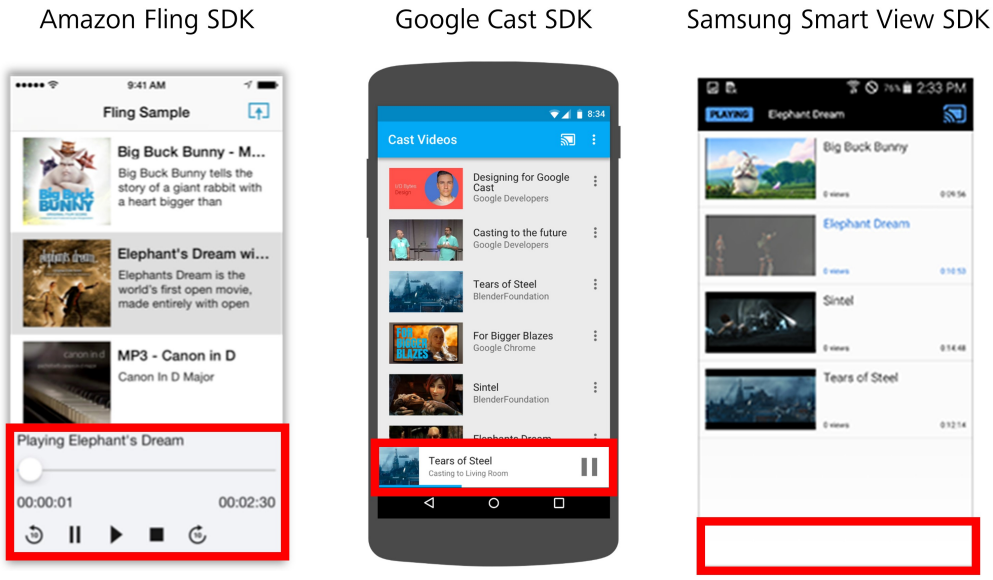

Figure 8-3: Control bar for the content of the first screen, available while browsing on the second screen, found in existing guidelines except Samsung's.

Overview

Similar design recommendation by the manufactures

The general concepts for establishing a connection and controlling the content are similar in the examined guidelines. The occurring differences can be seen in most cases complementary and not contradictory. Table 8-1 gives an overview of the aspects discussed, which are also examined in existing second screen applications in the following.

	Amazon	Google	Samsung
Cast button visibility	X	X	X
Status *connecting*		X	X
Feedback first screen			
Control bar	X	X	

	Amazon	Google	Samsung
Playback controls	X	X	X
Lock screen controls		X	

Table 8-1: Overview on most important differences and intersections between the analyzed manufacturer's guidelines.

8.2.2 Analysis of Existing Second Screen Applications

Comparison of recommended and actual design

The guidelines concerning the design of second screen applications analyzed in the previous chapter represent the *recommended* state of applications. Here, concepts in already existing applications are surveyed and put in relation to the previous manufacturers' guidelines to make a comparison with the *actual* state of second screen applications.

Selected applications

The selected existing applications should offer a similar functionality as the examples from the guidelines for better comparison. *Amazon Prime Video*, *Netflix*, and *YouTube* have been selected in this context as the most popular media library applications, which are also among the most popular second screen applications. In October 2018, *Amazon Prime Video* has over 50 million (Amazon Mobile LLC, 2018), N*etflix* 100 million (Netflix, 2018), and *YouTube* one billion downloads in the *Android Playstore* alone (Google LLC, 2018). Furthermore, two of the applications, *Amazon Prime Video* and *YouTube*, were developed by companies whose design recommendations were examined in the previous chapter. The most important intersections and differences found in the existing applications are again subdivided into the connection process and control of the first content.

Connection Process

Deviating connection process with A*mazon Prime Video*

The connection process with *Netflix* and *YouTube* matches the previous identified dominant pattern of a cast button in the upper right corner that is visible and accessible from every screen. *YouTube* skips the selection of a first screen when only one device is available and has been previously connected, which is considered a useful addition. Establishing a connection with A*mazon Prime Video* is only possible from the actual content pages. This not only contradicts the established

concept for permanent visibility and access to the connection button, but also removes the choice of connecting *before* or *after* the content selection (cf. Chapter 8.2.1). It is noteworthy that *Amazon* also contradicts its own recommendations for the design of second screen interaction with this behavior, which was also assessed negatively in the later user test (cf. Chapter 8.2.3.2). Another difference between *Amazon Prime Video* and the other two applications is the independence from the current local network, which requires an account bound synchronization. Figure 8-4 shows the differences in the connection process of *Amazon Prime Video* compared to *Netflix* and *YouTube*.

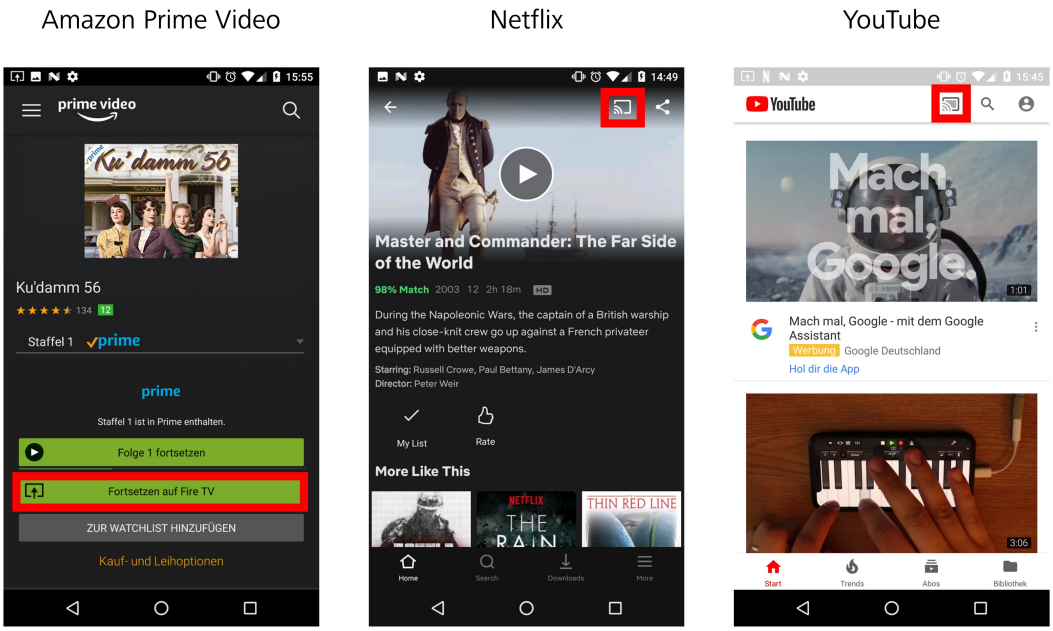

Figure 8-4: Different connection process with *Amazon Prime Video* compared to *Netflix* and *YouTube*.

Control

General control

During a connection, *Netflix* offers additional control elements such as a timeline, subtitles, or volume control as an extension of the control bar. *YouTube* has a mostly similar behavior, but also offers a playlist of videos on the remaining screen instead of a thumbnail of the current content. This is a good example of additional information displayed on the second screen. *Amazon Prime Video* has a similar concept of playback control, but it is less accessible due to the absence of a control bar. The current content on the first screen can only be controlled by

explicitly navigating to the corresponding content page on the second screen or by using the lock screen controls. Apart from that, the informational functional scope of *Amazon Prime Video* exceeds that of the other two applications. With the *X-Ray*[82] function, additional information is displayed directly on the second screen, which synchronized with the current time of the first screen content. This additional information includes the actors in the current scene, with short biographies and other films they have taken, or information on the current music. Figure 8-5 shows the missing control bar in *Amazon Prime Video* compared to *Netflix* and *YouTube*.

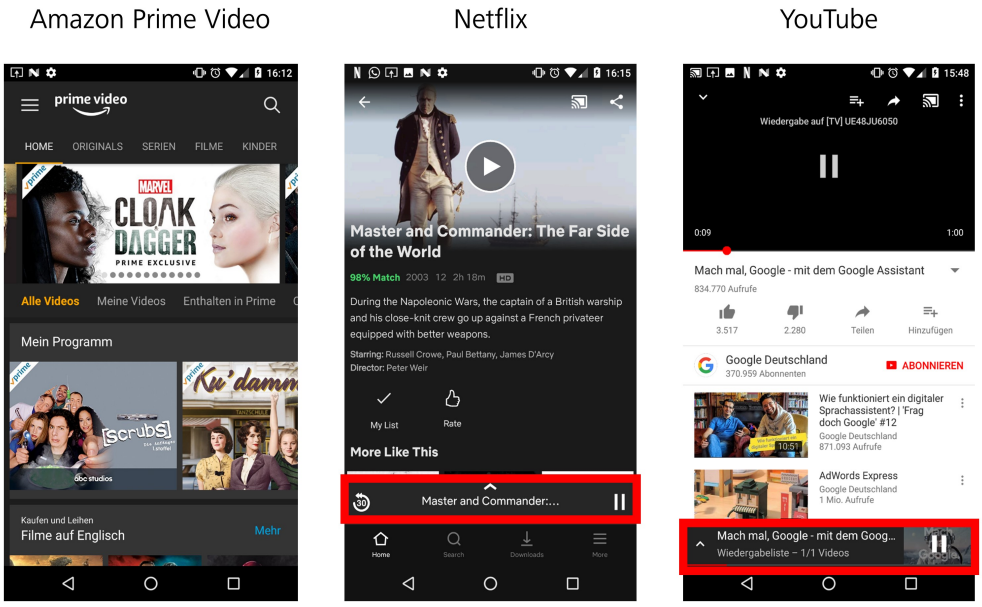

Figure 8-5: Missing control bar in *Amazon Prime Video* in comparison to *Netflix* and *YouTube*.

Different concepts for video winding

For all three applications, different concepts for rewinding were found apart from the selection with the timeline. While *Amazon* offers a button for fast forward and rewind (each ten seconds), *Netflix* limits itself to rewinding 30 seconds. *YouTube* offers the possibility of double clicking on the left side of the video for rewind and the right side for fast forward, for each ten seconds. These differences were examined in more detail in the user study, which is described in the next chapter.

[82] https://www.amazon.de/gp/help/customer/display.html?nodeId=201423010

Overview

Amazon Prime Video deviates from the common concepts

The applications examined are not as uniform as the recommendations in the previous guidelines. *Amazon Prime Video* repeatedly breaks with the common concepts of connectivity and control, and its own guidelines. This is particularly noticeable in the basic concepts of the cast button and the control bar. The control of the first content itself was similar, even though there are minor differences in rewinding and fast forwarding within a video. Lock screen controls were found in all applications, but was only recommended in the guideline by *Google*. In the next chapter, the different concepts are assessed in a user test.

	Amazon	Google	Samsung	Amazon Video	Netflix	YouTube
Cast button	X	X	X		X	X
Status *connecting*		X	X		X	X
Feedback first screen						X
Control bar	X	X			X	X
Playback controls	X	X	X	X	X	X
Lock screen controls		X		X	X	X

Table 8-2: Overview of selected aspects of connection and control between analyzed guidelines and existing applications.

8.2.3 Evaluation of Raised Concepts

Integration of users in the development of the design guidelines

Guidelines can help to design concepts in a meaningful way, but without the involvement of users in the design process it is not possible to ensure that the desired requirements are met, especially for novel products (Malaka et al., 2009, p. 361). Therefore, a user test was conducted to assess the prior identified concepts for establishing a connection and controlling content, in order to provide well-founded design recommendations for second screen applications.

8.2.3.1 *User Study*

The user study was carried out using the three previously examined second screen applications *Amazon Prime Video*, *Netflix*, and *YouTube*. These existing solutions represent the individual concepts best, as they are in real use.

Tasks

The test consisted of two general tasks, one for the connection process and one for content control. First, the corresponding application was opened and a connection to the first screen was established. In the second task, a video was selected and played on the first screen. After navigating on the main screen of the second screen application, the participants were instructed to view the previous scene again. Since there are different ways to solve this task with every application, the task was formulated in a rather general way to prevent any influence on the completion approaches of the participants. In order to ensure a uniform test procedure for all three applications, the same content was selected for the second task, which was an excerpt from the series *Family Guy*.

Participants and procedure

The tasks were carried out by 36 participants (15 female, 21 male) with an average age of 24 years and a range of 21 years. The participants first completed a questionnaire on their demographic data and their previous experiences on second screening in general and the applications tested. After completing the tasks on one of the applications, the participants filled out a questionnaire regarding their experience with the application used (Appendix E.2.1). To capture the instrumental and non- instrumental qualities of the applications, an adapted approach for the evaluation of UX of second screen applications was used, consisting of a combination of the *System Usability Scale* and *AttrakDiff* (Abreu, Almeida, & Silva, 2016, p. 113). After the tasks for all three applications had been completed, participants were interviewed on their overall experience (Appendix E.2.2). The study was conducted in a laboratory modelled on a living room to create a test environment as realistic as possible. The test was conducted on an Android device as second screen, and a *Fire TV* stick as first screen, for the test of the application *YouTube* a *Chromecast* was used, because this application is no longer officially available on *Fire TVs*. The sequence of the tested applications was

alternated to reduce bias of the data collected. The most important findings of the conducted study are presented in the following.

8.2.3.2 *Results User Study*

Results connection process

The results of the user study confirm that a deviation of the prevailing processes in establishing a connection and in the content control reduces the usability of second screen applications. The concepts of *Netflix* and *YouTube* are very similar and were rated equally well in the user study. *Amazon Prime Video* was perceived as not well structured during the connection process and caused more problems and frustration overall. Cause for the negative perception of the connection process was the absence of a cast button, which allows control over the connection and shows the respective connection status throughout the application. The missing choice of connecting *before* or *after* the content selection was also criticized (cf. Chapter 8.2.1). The findings regarding the connection process are shown in Figure 8-6.

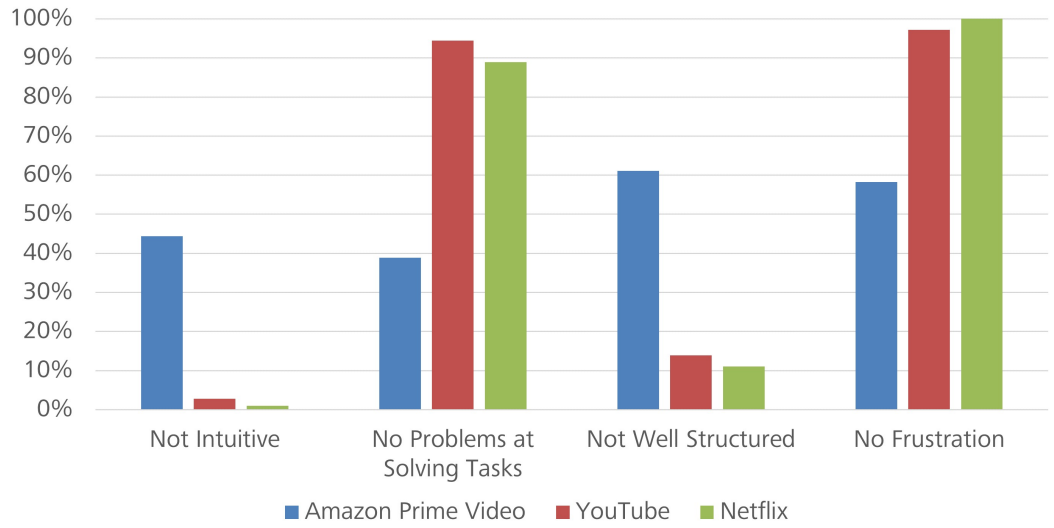

Figure 8-6: Results of user study on the connection process.

Results control with second screen

Netflix and *YouTube* were again rated similarly well in terms of control aspects, as they use a similar concept. There was no clear preference between rewinding based on the timeline and buttons, so both alternatives should be available. The rewind and fast forward function of *YouTube* by double-clicking in the video was only known to 17% of the participants. After the participants were made aware

of this function in the post-questionnaire, it was esteemed as acceptable solution. Nevertheless, buttons seem to be the better choice due to their better affordance.

While *Amazon Prime Video* was the overall worst rated application due to the lack of conformity to the common behavior, the playback controls received the most positive feedback of the three tested applications. The thereby available fast forward and rewind buttons skip ten seconds each, in contrast to *Netflix*´s thirty seconds. The absence of the control bar was often criticized, because the content can only be controlled by navigating to the current content page on the second screen. This tension between good control and poor accessibility is a possible reason for the mixed results of *Amazon Prime Video* shown in Figure 8-7.

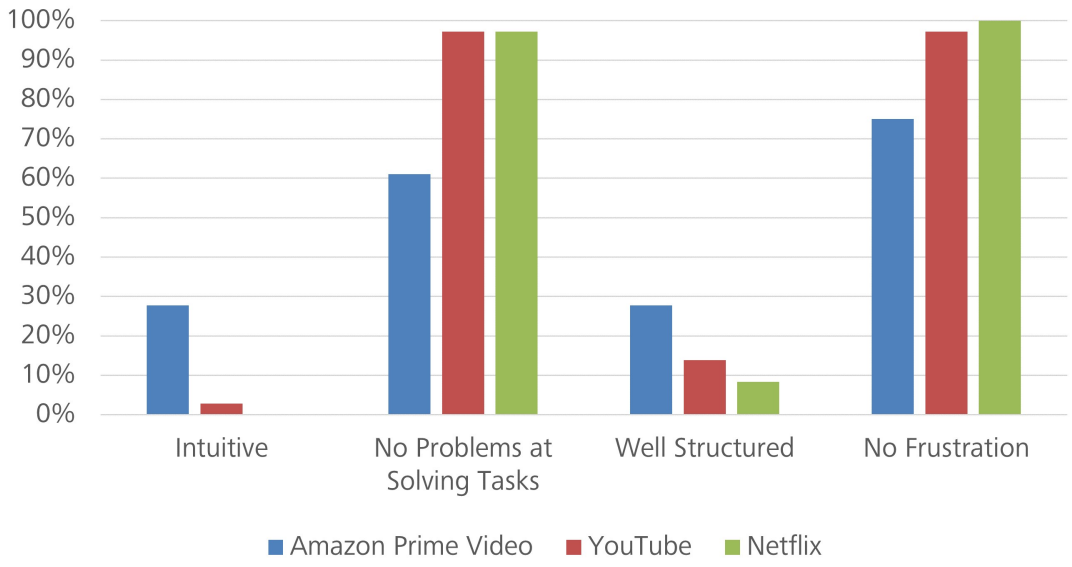

Figure 8-7: Results of user study on second screen control.

None of the three applications was found to be an ideal solution, and single aspects were criticized in all cases. Overall, the applications that have taken into account the recommendations of the manufacturers' guidelines were significantly better evaluated. The problems found with *Amazon Prime Video* are also reflected in the total SUS score shown in Table 8-3. The insights of the user study were also incorporated into the guidelines presented in the next chapter.

	Amazon Prime Video	Netflix	YouTube
Total SUS score	54.0	90.3	87.5
95% confidence interval	7.23	3.19	3.79

Table 8-3: *System Usability Scale* of applications surveyed in the user study.

8.3 Unified Guidelines for Second Screen Applications

Development of the guidelines

The guidelines presented here are the result of multiple studies conducted in this work, mainly the analysis of existing design recommendations by different manufacturers (cf. Chapter 8.2.1), the most distributed existing second screen applications (cf. Chapter 8.2.2), and a user study to assess the different identified concepts (cf. Chapter 8.2.3). Beyond that, different insights gained during other parts of this work, as the studies on attention guidance (cf. Chapter 7) and the development of the heuristic checklist, were also incorporated (cf. Chapter 9). The visualizations presented are deliberately kept minimalistic to emphasize the most important aspects instead of proposing complete designs. The guidelines are developed with regard to media library applications, as these currently represent the most distributed second screen application type. Other types of second screen applications can use the basic concepts presented here and adapt them to the respective contexts.

8.3.1 Connection Process

The connection process describes the presumably most important step in second screen applications, in which both application parts are linked to be perceived as unified system. Thereby are four consecutive steps differentiated, which are described in the following (Figure 8-8):

1. Display of an available connection.
2. Device selection (optional).
3. Feedback during connection setup.
4. Feedback regarding success or failure of the connection.

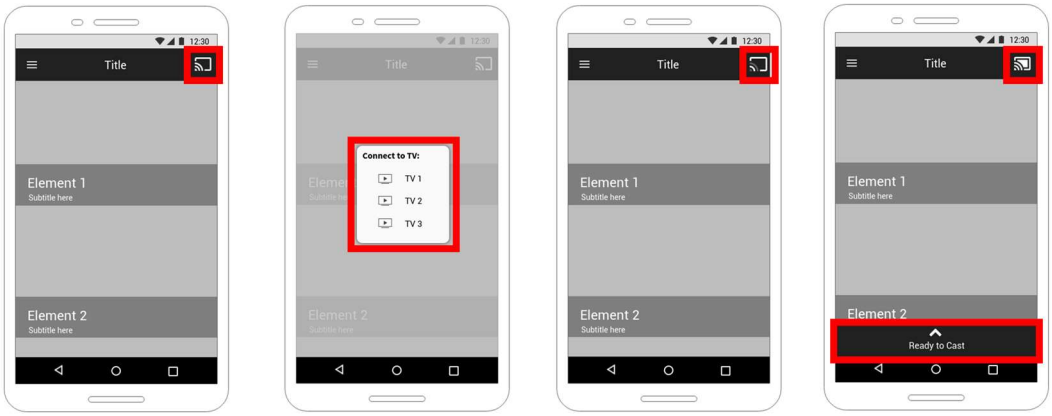

Figure 8-8: Schematic connection process.

Display of an available connection

Cast button

A possible second screen connection is indicated by the display of a *cast button*. This cast button is available on every screen of the application and is typically located in the upper right corner, although this position may differ. The cast button should use the usual icons for *iOS* and *Android*, whereby the examples used here showing the wider distributed platform *Android*. The connection can be established at any time, e.g. *before* or *after* content is selected. If the connection is disconnected and the reconnection fails, the cast button is reset; if the connection is no longer available, the cast button is no longer displayed.

Device selection

Device selection

Selecting the cast button should trigger a list of available devices, if possible with device type and name. Selecting a device automatically closes the connection dialog and returns to the previous screen. The selection of devices is optional if only one device is available that is already known because it was previously connected.

Feedback during connection setup

Connecting status

After selecting a device, the application should provide continuous feedback on the status of the connection. Typically, this is indicated by an animation of the waves in the cast button. If possible, the first screen should also provide feedback that a connection is in process to increase the feeling of a coherent application.

Feedback on the success of the connection

Successful connection

A successful connection is shown by a filled-in cast button and the display of the control bar on the second screen. The first screen should also give feedback on a successful connection, ideally with the name or type of the connected device. This is not necessary on the second screen because the connection was initiated from this side. The control bar offers no function if no content is selected, except for a consistent design and positive feedback about the connection status. Selecting the connected cast button offers the option to disconnect the current connection and provides information on the currently connected device. If the connection could not be established, the application returns to the initial state with an error message.

8.3.2 Control

Content selection

Selecting content on a connected second screen automatically plays it on the first screen, but checks for confirmation if another content is currently played. If a playlist function is available the content should also be queued, which triggers according feedback on the first screen. Figure 8-9 shows the control bar when playing content with three design examples for the expanded control bar.

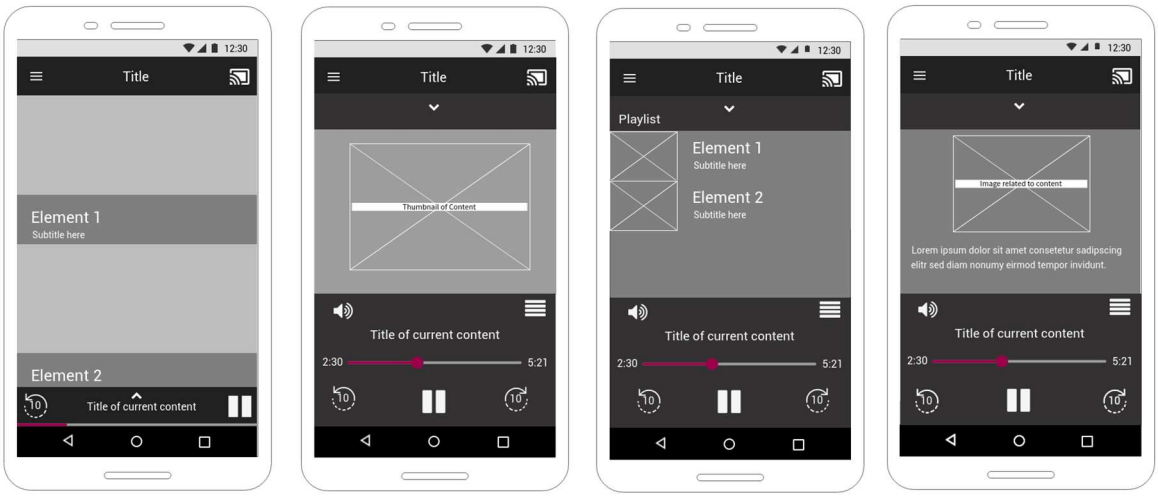

Figure 8-9: Compact control bar (left) with three design possibilities for the expanded view.

Compact control bar

The compact version of the control bar is accessible from every screen of the application and displays the name of the current content, an option to rewind ten second, and the option to pause or resume the current content. For informative purposes, the current progress should be displayed in a time line below the control bar.

Expanded control bar

Expanding the control bar opens a more detailed view with additional controls. The timeline should offer a more detailed navigation, ideally with thumbnails. Additionally, buttons should be available for a finer time selection, each winding ten seconds back or forward. This amount of time should be adaptable in the settings of the applications to the needs of the users. Furthermore, additional settings like volume or subtitles should be available in the expanded control bar.

Design of expanded control view

The remaining space of the expanded control view can be designed according to the needs of the current application. The most basic variant is an image related to the current content, but it is also possible to display the elements of a playlist and the corresponding interactions if this function is supported. Potential second screen components that can be integrated here are presented in Chapter 6.3, such as *information*, *social*, *game*, or *other* components.

Lock screen control

Apart from the control bar, lock screen controls are a useful addition to make the control of the current content outside the application more direct. These should display the current title, playback control, and a rewind button.

8.3.3 Notifications

General design of notifications

The design and coordination of notifications are an important part in second screen applications in order to perceive the two parts of the application as a coherent system. In general, notifications should be designed in such a way that the second screen does not attempt to distract from the first screen, but rather to supplement its content. In the following, the most important results from the two studies on attention guidance (cf. Chapter 7) and literature on the design of notifications are presented:

Second Screen Notification

Second screen notifications

Haptic notifications on the second screen are the best way to display important information. V*isual* notifications are suitable for background and not time-relevant information, as a*uditive* and *haptic* notifications can be perceived as disruptive. Notifications should be spaced by an interval of at least 30 seconds in order to prevent tiring and distraction effects (Abreu, Almeida, Silva et al., 2016, p. 909). A timer that shows the time until the next notification is useful. Notifications already displayed should be available in the application. The information density specified in the notification should be adapted to the content of the first screen so that, for example, exciting scenes are not interrupted and the user's immersion is thus interrupted.

First Screen Notifications

Importance of subtle design

The main part of attention while second screening is focused on the first screen, which is why notifications play a subordinate role here (cf. 7). Nevertheless, visual notifications on the first screen are desirable with the appropriate design. In general, these notifications should be subtle, only be used for important information, customizable, and deactivatable, since for some people no notification is important enough to distract them from their immersion (Weber et al., 2016, p. 22). The upper right corner is preferred by users to display notifications, but the position can vary as long as it is in a corner. *Auditive* notifications should only be used for important changes in the redirection to the first screen. A redirection to the first screen using the second screen does is unsuitable, as this behavior tends to confuse the users. The distribution of additional information on first and second screen makes it easier to follow content, but must be adapted to the context of the content.

8.4 Summary Design Guidelines

Guidelines development

This chapter presents recommendations on the design of second screen applications, in particular media library applications. The design guidelines were created by an analysis of existing design recommendations by different manufacturers and currently established concepts in existing applications. The identified concepts were assessed in a user study with 36 participants to provide a reasoned recommendation. Aspects identified in other studies of this work were also incorporated in the presented recommendations.

Guidelines content

The guidelines provide reasoned recommendations on the design of basics concepts in second screen applications: the *connection process* between the two applications parts and the *control* in a multi-component system. In order to manage the connection between these parts a *cast button* available on all screens was proposed. For the control of the first screen content a *control bar* that can be expanded for more information and control options. The guidelines are presented with visual design recommendations to aim to ease their use.

9 A Heuristic Checklist for Second-Screen Applications

Chapter structure

While the previous chapter provided insights that are intended to support the development process of second screen applications, this chapter introduces heuristics for the evaluation of these applications. The chapter is structured as followed: Chapter 9.1 provides a short overview on the field of research on *heuristic evaluation*, where the most important aspects are presented. In Chapter 9.2 the development process of the heuristics for second screen applications and the extension to a heuristic checklist is described. The actual heuristics and created checklist are presented in Chapter 9.3. Chapter 9.4 describes the evaluation of the heuristics, before finally, a brief summary is presented in Chapter 9.5[83].

9.1 Background Heuristic Evaluation

Usability evaluation methods

The evaluation of design concepts from early stages on is an essential activity in a human-centered design process and aims after its definition for the following goals (ISO, 2010, p. 22):

- Collection of new information about user needs.
- Provision of feedback on strengths and weaknesses of the design solution from the user's perspective, in order to improve the design.
- Assessment whether user requirements have been achieved.
- Comparisons between different designs.

This process is to been seen iterative and should be performed from the earliest stages on, in order to create software that meets the user's needs.

[83] The results of Chapter 9 are published as:

- Lohmüller, V., Schmaderer, D. & Wolff, C., (2018). Heuristiken für Second-Screen-Anwendungen. In: Dachselt, R. & Weber, G. (Hrsg.), Mensch und Computer 2018 - Tagungsband. Bonn: Gesellschaft für Informatik e.V. https://doi.org/10.18420/muc2018-mci-0266
- Lohmüller, V., Schmaderer, D. & Wolff, C., (2019). A Heuristic Checklist for Second Screen Applications. i-com: Vol. 18, No. 1. Berlin: De Gruyter. (S. 55-66). https://doi.org/10.1515/icom-2019-0003

Formative and summative evaluation

Evaluation approaches can be either *formative* or *summative*. Formative evaluation is done *during* development to improve a design, and summative evaluation is conducted *after* the development to assess a design. Technically, usability evaluation methods can be used for both, but convention is to limit the term to formative approaches, due the main goal to determine and resolve usability problems iteratively, before actual users are confronted with them (Hartson, Andre, & Williges, 2003, p. 149).

User- and inspection-based evaluation

The de facto standard in usability evaluation methods is a laboratory-based usability test with actual or potential users (Hartson et al., 2003, p. 151). These usability tests examine the completion of tasks within the design solution and the problems that occur while solving them, but not the users' opinion, which is obtained in user surveys. However, evaluation by users is not always practical or cost-effective at every stage in a design process. In this circumstances, design solutions can also be evaluated in others ways, such as in an inspection-based approach (ISO, 2010, p. 22). Inspection-based evaluation describes methods where evaluators, mostly experts, examine usability-related aspects, for example *cognitive* or *pluralistic walkthroughs*, or the most distributed method in this approach *heuristic evaluation*, which is further elaborated in the following (Ling & Salvendy, 2005, p. 180; Sears, 1997, p. 219). Figure 9-1 shows the two different approaches for usability evaluation, with its most distributed methods.

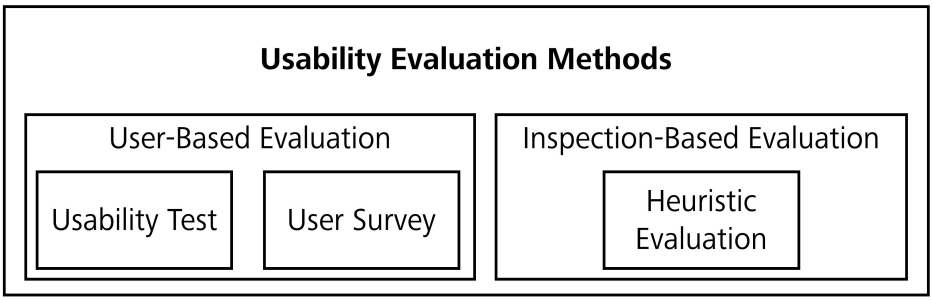

Figure 9-1: The two different approaches for usability evaluation, user- and inspection-based evaluation, with their most distributed methods.

Heuristic evaluation overview

Heuristic evaluation is an informal usability evaluation approach that was introduced by Nielsen and Molich in 1990. In this approach evaluators produce lists of usability problem by inspecting a user interface freely and noting deviations

from accepted usability principles, so called *heuristics* (Ling & Salvendy, 2005, p. 180). Each problem is documented, including the violated heuristic and enough context to help understand the problem, and assigned a severity rating (Sears, 1997, 216f.) The evaluation is ideally performed by usability experts, who base their judgment on previous experience and existing standards, and is repeated by multiple experts to reduce individual bias (ISO, 2010, p. 18). Heuristic evaluation is considered as cheap, fast, and easy to use, while achieving a satisfactory result and is therefore also references as *discount usability method* (Nielsen, 1994, p. 25).

Heuristic walkthrough

The concept of a free-form evaluation with a list of usability heuristics by Nielsen and Molich, was later adapted by Sears (1997) to a more structured technique, the *heuristic walkthrough*. This derivation combines aspects from heuristic evaluations and cognitive walkthroughs, and consist of guided phase with a prioritized list of users tasks, a list of usability heuristics, and a free exploration phase of the system (Sears, 1997, p. 219). The here introduced *heuristic checklist for second screen applications* (cf. Chapter 9.3.2) combines aspects from these two approaches. It provides more structure than a heuristic evaluation and causes less effort than a heuristic walkthrough, because it only consists of one phase and does not need generated tasks.

Heuristic evaluation origin

The first set of heuristics originated from the need to cut down the complexity of evaluating user interfaces, caused by the high number of guidelines available, which were time-consuming and difficult to use (Ling & Salvendy, 2005, p. 180). Nielsen and Molich (1990) derived the original list of usability heuristics by their understanding of typical problem areas and an informal consideration of existing guidelines. The first set compassed nine usability heuristics, the tenth, *help and documentation*, was added later in 1991 (Nielsen, 1994, p. 29):

First draft of Nielsen's heuristics

1. Simple and natural dialogue
2. Speak the user's language
3. Minimize user memory load
4. Be consistent
5. Provide feedback

6. Provide clearly marked exits
7. Provide shortcuts
8. Good error messages
9. Prevent errors
10. Help and documentation

Nielsen's ten usability heuristics

Nielsen later performed a more formal study, which encompassed 101 usability principles including the set listed above, to evaluate eleven interactive systems. The seven factors with the most explanatory power for the most usability problem formed the basis for the revised set of heuristics, to which Nielsen added three heuristics based on his own experience (Ling & Salvendy, 2005, p. 180). The result is a revised set of usability heuristics, which is widely used among literature and also states the basis for the heuristics for second screen application introduced in this work (Nielsen, 1994, p. 30):

1. Visibility of system status
2. Match between system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognize, diagnose, and recover from errors
10. Help and documentation

Heuristic evaluation in other domains

The original heuristic evaluation was developed and applied mainly for single user, productivity-oriented desktop programs, which were the majority of computer applications in the 1990s. Computer technologies have become more integrated into everyday life and versatile since then, to that degree that Nielsen´s ten heuristic may not be able to cover all usability issues in modern systems (Ling & Salvendy, 2005, p. 183). Therefore, the original heuristics are not readily appli-

cable to many new domains, but can be adapted to address the typical requirements and problems in certain areas. Examples are heuristics for augmented reality applications (Guimaraes & Martins, 2015), information appliances (Böhm, Schneidermeier, & Wolff, 2014), or game design (Pinelle & Wong, 2008). Heuristics[84] and guidelines[85] exist in the areas of second screen and smart TV as well, but no statement is made about their validity in the respective studies. These works are discussed further in Chapter 9.2. The development of heuristics for second screen applications follows the recommendations of Ling and Salvendy (2005, p. 193), who encourage the development and refinement of more domain-specific heuristics to create more precise and relevant evaluation results, and by that improve the usability of that domain.

Heuristic checklist

A general disadvantage of heuristics and similar principles is their high degree of abstraction, which results from the universal and vague formulation and allows a number of different interpretations by the evaluators (Böhm et al., 2014, p. 277). To compensate for these different interpretations, the heuristics can be further concretized or extended to the second-level heuristics by a more thorough formulation or by adding instructions from design guidelines (Ling & Salvendy, 2005, p. 186). These more detailed descriptions, on the other hand, make the application of the heuristic evaluation less manageable and increases the cognitive burden on the evaluators. In order to give precise instructions, to enable a low-effort evaluation, and to keep the results consistent between different evaluators, the heuristics can be formulated in form of checklist (Guimaraes & Martins, 2015, p. 51), which was done in this work and is elaborated in the following.

[84] Mosqueira-Rey et al. (2017); Solano et al. (2011)
[85] Weber et al. (2016); Pagno et al. (2015)

9.2 Development of the Heuristics for Second Screen Applications

Evaluation- and research-based derivation

According to Ling and Salvendy (2005, p. 186), domain-specific heuristics can be developed following two different approaches: the *evaluation-based* and the *research-based* approach. In an evaluation-based approach, general usability problems with certain systems are categorized in heuristics. This type of derivation is based on empirical observations and is often dependent on the examined object and therefore less suitable for the derivation of generic heuristics (Böhm et al., 2014, p. 278). The research-based approach identifies requirements and key factors of a specific domain based on appropriate literature. This method is similar to Nielsen's approach to the original heuristics, which were also synthesized from a number of existing guidelines, and thus represents a research-based approach (Hvannberg, Law, & Lárusdóttir, 2007, p. 226). This approach was chosen in order to develop a domain-specific heuristic based on existing literature in the field of heuristics and guidelines in the area of second screen.

Second screen heuristics related work

The literature used to extend Nielsen's set of usability heuristics to second screen applications is divided in existing *heuristics* and *guidelines*. Mosqueira-Rey et al. (2017) formulate heuristics based on an evaluation of a single second screen application. While the resulting six heuristics contain valuable aspects, the transferability on other applications and general validity are not investigated. The usability heuristics by Solano et al. (2011) are intended for the evaluation of interactive digital television, which is considered as closely related to the subject of second screening. The 14 resulting heuristics were created by the authors understanding of characteristics of the targeted domain and a categorization process, based on Nielsen's set. Again, no validation of the created heuristics was carried out in Solano's work, although it is considered mandatory by the literature (Hartson et al., 2003; Rusu, Roncagliolo, Rusu, & Collazos, 2011; Sears, 1997).

Second screen guidelines related work

Guidelines typically contain more concrete instructions than heuristics, which is why they were used in the second step of the development process to create the checklist. The guidelines by Pagno et al. (2015) were created as a summary of a series of experiments on dynamic second screen applications, but were

not evaluated in the paper. Weber et al. (2016) derived design guidelines for notifications on smart TVs based on their findings from a series of focus groups, an online survey, and a controlled lab study. Smart TV notifications are a central aspect in the first screen design and in many aspects transferable to the second screen, and therefore relevant. The guidelines are the result of various studies, but no statement is made regarding their quality.

All of the mentioned literature is assigned to the evaluation-based approach, which categorized empirical problems. The described findings hold valuable insights, but lack generalization and validation, which is why they were chosen in this work as a supplement to the resulting heuristics.

Development procedure overview

The development of heuristics for second screen applications included the following steps[86]: A set of existing heuristics was chosen as a basis, which was adapted and supplemented with the help of appropriate literature (Ling & Salvendy, 2005, 183ff.). In order to keep subjective influences as low as possible, a focus group of experts from the target area was formed. The result represents the first level of heuristics, which was further concretized with additional literature to the heuristic checklist. Figure 9-2 shows the sequence of steps in the development of heuristics.

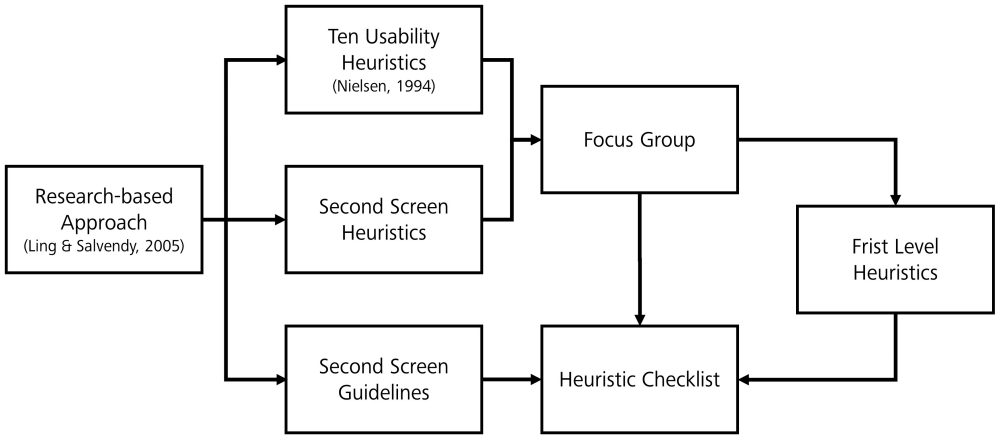

Figure 9-2: Development procedure for the heuristic checklist for second screen applications.

[86] The execution of the derivation of heuristics for second screen applications was part of the bachelor's thesis of Daniel Schmaderer, who executed the here mentioned steps, supervised by the author.

9.2.1 Research-Based Derivation of the First Level Second Screen Heuristics

First-level heuristics development

The *Ten Usability Heuristics* by Nielsen (1994) form the basis of the adapted heuristics due to their high distribution and extensive use (Rusu et al., 2011). These were supplemented by the already existing domain-specific heuristics of Mosqueira-Rey et al. (2017) and Solano et al. (2011). This process was supported by a focus group of two experts, with two and a half years experience in the field of second screen development to identify named and semantic duplicates in the presented heuristics, group topics, find less relevant heuristics in the field of second screening, and to extend the new heuristics by domain-specific points. Eight of Nielsen's original heuristics were found to be transferable and were adapted to the new domain, and two new heuristics were added specifically for second screen applications. The complete list of heuristics for second screen applications is presented in Chapter 9.3.1. The total number of ten heuristics was intentionally not exceeded, following the example of Nielsen (1994). Although a higher number of heuristics potentially identifies more usability problems, it also represents a higher cognitive burden for the user, which is why the total number of heuristics should not become too large (Ling & Salvendy, 2005, p. 192; Nielsen & Molich, 1990). This set forms the first-level of heuristics for second screen applications and are formulated more comprehensively than the original set due to their specialization. Therefore, and to counteract the weakness of lack of structure in conventional heuristic evaluation (Ling & Salvendy, 2005, p. 182), a heuristic checklist with concrete and precise instructions was developed in the second stage to facilitate the use of the heuristics.

9.2.2 Derivation of the Heuristic Checklist for Second Screen Applications

Heuristic checklist development

For the creation of the heuristic checklist, individual checklist *items* were generated from the existing heuristics[87] and guidelines[88] in the target domain. These items were formulated as precisely as possible and referred to single aspects identified in literature. A total of 66 points were created, of which 51 were then incorporated into the previously created first-level heuristics for better overview. Due to their concrete and practical nature, guidelines are well suited for extending heuristics to be more precise (Böhm et al., 2014, p. 277), which is why they were combined with the previously gained findings from the focus group. The result of the heuristic checklist for second screen applications is described in section 9.3.2.

9.3 Heuristics for Second Screen Applications

Overview development heuristics

Based on Nielsen's (1994) *Ten Usability Heuristics*, a set of domain-specific heuristics for second screen applications was created in a research-based approach with the help of a focus group and specific literature. This set is more comprehensive than the original heuristics due to its specialization, which is why a heuristic checklist was derived from it to increase the manageability and given structure in the evaluation process. For this purpose concrete checklist items were generated from literature and classified into the previously created first-level heuristics. In the following, the set of first-level heuristics for second screen applications (cf. Chapter 9.3.1) and the heuristic checklist (cf. Chapter 9.3.2) are presented:

9.3.1 First-Level Heuristics for Second Screen Applications

1. *Visibility of system status*: The system should always keep the user up to date by providing appropriate feedback in a reasonable time. The user should have an overview of the current connection status between first and second screen at all times. The current content on the first screen should always be visible on the second screen to give the user a good

[87] Mosqueira-Rey et al. (2017); Solano et al. (2011)
[88] Weber et al. (2016); Pagno et al. (2015)

overview of both parts of the application. Both parts of the system should display the same status.

2. *Match between system and the real world*: A second screen application should speak the language of the user. Words, phrases, and the concept of the second screen application should be presented in a natural order. If this is not the case, difficulties in using the application will increase. Especially in the connection process of the second with the first screen, complicated technical terms could make the operation more difficult or even impossible.
3. *User control and freedom:* The user should always have control over the content of the first screen when connected.
4. *Consistency and standards*: The design and layout of the interface as well as the user interaction should be consistent on both screens. In addition, standardized icons, conventions, and terminology should be used.
5. *Error prevention:* The design and explanation of a second screen application should prevent the occurrence of errors as far as possible. If errors do occur, it is important to describe them as clearly and concisely as possible in order to make it easier for the user to handle the error messages.
6. *Recognition rather than recall:* Objects, options, and actions should be visible and recognizable in second screen applications. The user should be aware of his possibilities in all areas and not have to remember them.
7. *Aesthetic and minimalist design:* A second screen application should not occupy the user with irrelevant information as it distracts him from the relevant information. This is especially important when the system is communicating with the user. Notifications should be subtle and not too frequent. Effects and animations should be used with care to avoid distracting the user.
8. *Help users recognize, diagnose, and recover from errors:* If errors occur in a second screen application, the help should be formulated in the user's language. In the case of errors that the user can correct by himself, the error message should be accompanied by instructions for correcting the error.

In the case of errors that the user cannot fix, this should be clearly stated. The cause of the error should always be clear, especially in relation to the connection process.

9. *Connection process*: The connection process should be as simple as possible and available from anywhere. The first and second screens should be assigned the correct roles, with control on the second screen and media presentation on the first screen.
10. *Use a second-screen when it adds value:* A second screen application should only be used if it provides added value for users.

Extension to heuristic checklist

The adapted heuristics are intended for the same use as the original set of heuristics. It can serve as a basis for heuristic evaluations and walkthroughs and draw the evaluators' attention to important aspects regarding second screen applications. A known weakness of conventional heuristic evaluations is the unstructured process, supported only by the sometimes vague formulations of the heuristic (Ling & Salvendy, 2005, p. 182). In order to counteract this problem and to facilitate the evaluation process, the first-level heuristics were extended to a checklist, which is presented below.

9.3.2 Heuristic Checklist for Second Screen Applications

1. *Visibility of the System Status*
    a. Does the application give the user feedback?
        i. At performing key actions
        ii. At reasonable time
    b. Is the status of the connection kept updated?
    c. Are the screens keep synchronized instantaneously?
2. *Match between the system and the real world*
    a. Does the application speak the user's language?
        i. Understandable terms/descriptions
    b. Does the application show the information in a natural order?
    c. Does the sequence of activities follow the user's mental processes?
3. *User control and freedom*
    a. Is the navigation simple and intuitive for the operating system?
        i. Menu
        ii. Search bar
    b. Does the application provide different options?

    i. Return to top level
  c. Is the user able to explore the application freely?
  d. Is the user able to control the content of the TV at any time?
  e. Is the user able to manage the connection between the screens at any time?
4. *Consistency and standards*
  a. Does the application follow the design guidelines of the using platform?
  b. Is the consistency between the two applications given?
    i. Terminology
    ii. Controls
    iii. Graphics/Icons
    iv. Focus on one guideline (if multiple apply)

5. *Error prevention*
  a. Is there a help for novice users?
  b. Does the application provide appropriate error messages?
6. *Recognition rather than recall*
  a. Is the relationship between the controls and their actions obvious?
  b. Does the user know what options he has and where to go?
    i. Main elements of application always available
    ii. Help available if needed
7. *Aesthetic and minimalist design*
  a. Does the application only show relevant and necessary information to the user?
    i. Titles and headlines short but descriptive
  b. Is the application design appropriate?
    i. Distance between elements
    ii. Size
    iii. Placement
  c. Are the elements of the application visible?
    i. At the visual range of watching TV
    ii. At various types of lighting
  d. Are notifications subtle and not to frequent?
    i. At least 30 seconds apart?
8. *Help users recognize, diagnose and recover from errors*
  a. Does the application provide clear messages with indicating errors and solutions for errors?
    i. Connection error, application crashes, etc.
  b. Are the error messages written in an accurate way?
    i. Not blaming the user
    ii. Objective tone

   c. Does the application provide users a clear and simple help, in their own language?
9. *Discovery and Connection*
   a. Is the pairing of main and secondary display simple and intuitive?
      i. 1-3 clicks needed
      ii. Direct Response after pairing
   b. Is the separation between the two applications and devices clear?
   c. Is the main logic on the mobile device?
   d. Is the main content shown on the first screen?
10. *Use a second-screen when it adds value*
   a. Does the second screen add value to the first screen?
   b. Does the second screen improve the content navigation?
   c. Does the second screen give the user a better user experience?

Intended use of the heuristic checklist

The level of structure provided by the checklist is between a heuristic *evaluation*, where guidance is only provided by the set of used heuristics, and a heuristic *walkthrough*, which consists of a phase in which task completed and a second phase in which the application is examined freely (Sears, 1997, p. 219). This approach requires more preparation and tends to take more time during execution, which contradicts the low-effort character intended by heuristic evaluation. Therefore, the heuristic checklist is seen as a compromise that combines aspects of both approaches. The checklist is intended to be worked through systematically by the evaluators. The individual checklist elements are partly aimed at the general workflow, which encourages the evaluators to explore the application freely, and in part at the closer inspection at important aspects, such as the connection process or error handling. This allows a mixture of free-form evaluation and guidance during evaluation, which led to much positive feedback by the experts in the evaluation. This evaluation is part of the validation process of the here introduced heuristic checklist and is presented in the next section.

9.4 Validation of the Heuristic Checklist

Validation approach

The derivation of new heuristics generally consist of two steps: heuristic *development* and *validation*. All the literature from the second screen area that was used for the development of the heuristics have omitted this second step, although it is considered very important, which is why a first validation of the heuristic

checklist was carried out this work. In the validation phase, the newly developed heuristics are typically compared with Nielsen's original set by conducting empirical studies, or benchmarked with user testing results. The adapted set of heuristics is usually more effective than the original set because it fits the evaluated domain better, which makes this approach less meaningful (Ling & Salvendy, 2005, 183ff.). Therefore, a validation consisting of a heuristic evaluation with the developed checklist with the comparison of user tests was chosen.

9.4.1 Validation Methodology

Performance measures

Typically three measures are used for the evaluation of heuristics: *validity*, *thoroughness*, and *reliability* (Böhm et al., 2014, p. 281; Hartson et al., 2003, p. 160; Ling & Salvendy, 2005, p. 187; Sears, 1997, p. 214). The formulas used for the calculation of these measures are presented in the next chapter during their application; in the following, the general concepts of these measures are briefly discussed.

Validity

Validity describes the ratio of the *real problems* found to *all identified problems*, thereby describing the *correctness* of the identified problems by the evaluators. This measure is based on the concept of *precision*, used to describe information retrieval performances. It is also based on the belief that evaluators are able to identify issues as usability problems that are not actual problems. It can be argued, that any problem identified by users or experts is a problem worth further investigation and thus cannot be *false*, which contradicts this understanding of validity. This discussion remains controversial, but goes beyond the scope of this work. Nevertheless, validity is a standard measure for the comparison of interface evaluation techniques and holds value with correct interpretation (Sears, 1997, p. 214).

Thoroughness

Thoroughness indicates how many of the predicted problems are actually found, and is perhaps the most attractive measure, and based on the concept of *recall*. Similar to the calculation of recall the determination of the denominator is problematic, since it is difficult to know how many problems exist in total. Commonly the sum of all identified problem or all problems encountered by users are used, because these are found to be *real*, although this may not a perfect estimate (Hartson et al., 2003, p. 161; Sears, 1997, p. 215).

Reliability

Reliability is a measure of consistency of testing results across different evaluator. There are various approaches to calculating reliability, such as Pearson's *r* (Nielsen, 1994), Cohen's kappa, the ratio of standard deviation of the number of problems the average number of problems found (Sears, 1997), or Kendall's coefficient (Nielsen, 1994). Although it is usually desirable to achieve constant results among different evaluators, the total result of the group is relevant, not the ones by single experts. If the single evaluator find completely different results, and they are relevant, this variety should be encouraged (Hartson et al., 2003, 167f.).

Effectiveness

As mentioned before, validity and thoroughness are measures based on *precision* and *recall*, and are not sufficient on their own to make a statement about the overall effectiveness of the applied heuristic. This effectiveness is usually defined as the product of thoroughness and validity. Due to the quadratic relationship, the calculated result is strongly influenced by a low value, and represents the relation rather unsatisfactorily. Hartson et al. (2003, p. 166) therefore describe analogous the precision and recall the calculation of a weighted harmonic mean, the *f-measure*.

Applied evaluation approach

In order to calculate these values, a second screen application was evaluated by five experts with the help of the heuristic checklist and the collected results were compared with those from a usability study of 20 potential users. The object of investigation was a second screen application that was still under development (cf. Chapter 5.2). The aim was to identify problems regarding usability at an early stage before they affect end users. For a meaningful evaluation of reliability, further heuristic evaluations of second screen applications would have to be carried out, which was not possible in the first iteration, and therefore this measure was not calculated. Nielsen and Molich (1990, p. 255) recommend between three and five users of a heuristic evaluation for the most efficient determination of usability problems. The experts examined the application with the help of the checklist, classified found problems with regard to the heuristics and assigned a severity level according to Nielsen (1994) of 0, *no problem*, to 4, *must be solved*. Finally, the experts were asked about the heuristics used (Appendix F.1).

Approach user test

The usability problems in the application predicted in the heuristic evaluation were used to generate the tasks of the user study, in order to increase the power of user testing for exposing all predicted problems that really exist (Hvannberg et al., 2007, p. 227). For this purpose, semantic and content-related duplicates in the problems found were removed and grouped thematically. From the resulting groups, *feedback*, *help*, *error*, *connection*, *search*, *menu*, *video*, *navigation*, and *playlist*, tasks were created for the users that they are not directly confronted with the corresponding problems, but all problem areas were examined (Appendix F.2.2). The aim was to check to what extent the predicted problems correspond to the heuristic evaluation of real user problems. Finally, the *System Usability Scale* (SUS) (Brooke, 1996) of the examined application was surveyed and a partially structured survey was carried out. Figure 9-3 gives a schematic overview of the applied validation process of the created heuristic checklist. In the following, the first iteration of the process is further elaborated. The questionnaires used in the user test can be found in Appendix F.2.

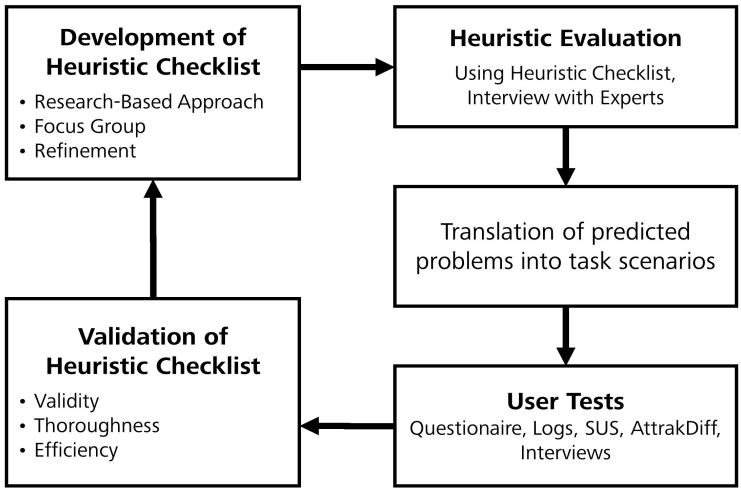

Figure 9-3: Schematic overview of the validation process of the created heuristic checklist.

9.4.2 Results of First Validation Iteration

Results first iteration

The iteration described here should be seen as the first step in a thorough validation. Additional second screen applications and heuristic evaluations can be included to gain even better insight into the heuristics developed here. The content of the heuristics can also be further adapted or extended in future work. In the following, the measures, validity, thoroughness, efficiency and f-measure, calculated from the first iteration in the validation process are described:

Validity

Heuristics have a high validity when as many as possible of the predicted problems from the evaluation match the *real / actual problems* of the users (Hartson et al., 2003, p. 163f.). The *real / actual problems* found are seen as the intersection of the problems found by users and experts.

$$Validity = \frac{number\ of\ real\ problems\ found\ (experts \cap users)}{number\ of\ issues\ identified\ as\ problems\ (sum\ experts)}$$

$$Validity = 14 \div 28 = 0.5$$

Measured validity

Of the 28 predicted problems, 14 were confirmed by users, resulting in a validity of 0.5 of the applied heuristics for the object under investigation. This value indicates a mediocre validity and suggests that rather different errors or a different amount was found between users and experts. The validity of a heuristic usually decreases with the number of evaluators, which is at the upper end of the suggested size in this study. Furthermore, the research object was still under development, which could be a reason for the rather high number of usability problems. Problems that have been predicted by experts and not confirmed by the users add value nevertheless to the development of an application, because these errors can be eliminated early on. The controversy of interpretation of false error in the context of validity was outlined in the previous chapter. Nonetheless, the high number of errors found by the experts outside the applied measures can be seen as positive for the development process, since this is where the real meaning

of a heuristic evaluation lies: the efficient and cost-effective identification of usability problems before actual users are confronted with them.

Thoroughness

Measured thoroughness

Thoroughness describes the number of existing problems that could be identified by the heuristic evaluation. Again, the intersection of the problems found is seen by experts and users as *real / actual problems* found and the sum of all user problems as the number of *real existing problems*. The problems of the experts not found by users thus turned out to be false positives and are taken into account in the validity (Hartson et al., 2003, p. 163f.).

$$Thoroughness = \frac{number\ of\ real\ problems\ found\ (experts \cap users)}{number\ of\ real\ problems\ that\ exist\ (sum\ users)}$$

$$Thoroughness = 14 \div 19 = 0.74$$

With a value of 0.74, the heuristic checklist is highly complete. This is partly due to the high number of problems identified by the experts.

Efficiency and F-Measure

The effectiveness of heuristics can be calculated based on the measures thoroughness and validity. This results from a simple multiplication of the two values.

$$Efficency = Validity\ x\ Thoroughness$$

$$Efficency = 0.74\ x\ 0.5 = 0.37$$

Measured efficiency

The rather low value 0.37 is due to the mediocre validity of the heuristics. Hartson et al. (2003, p. 165) notes the strong influence of a low value on this measure of effectiveness and describes a calculation of a weighted *F-measure*:

$$F = \frac{1}{\alpha(1\ /\ Validity\ ) + (1 - \alpha)(1\ /\ Thoroughness\ )}$$

Measured f-measure

An equal weighting of both values (α=0.5) results in an F-measure of 0.6, which describes a weighted mean between validity and thoroughness. This value lies in

the middle to positive range and describes an acceptable result of the heuristics in the first iteration.

9.5 Summary Heuristics for Second Screen Applications

Summary development heuristics

This chapter introduced general heuristics and an extended heuristic checklist for the domain of second screen applications. These heuristics were derived in a research-based approach on basis of Nielsen (1994) *Ten Usability Heuristics*, which were adapted and supplemented with the help of appropriate literature from the field second screening. In order to keep subjective influences as low as possible, a focus group of experts from the target area was formed, who created the first level of heuristics for second screen applications. A heuristic checklist was created with the help of further literature and the insights from the focus group, to ease the use of the heuristics and to counteract one of the most criticized aspects of heuristic evaluation, the loose and unstructured evaluation process only supported by the list of used heuristics (Ling & Salvendy, 2005, p. 182).

Summary validation

To assess the quality of the developed heuristics, a heuristic evaluation with five experts and the created checklist was conducted. The predicted problems were matched with the results of a user test of the same second screen application. The results indicate a mediocre validity of 0.5 and an acceptable thoroughness of 0.74. The weighted mean of these measures results in a sufficient efficiency of 0.6 of the developed heuristic checklist for the first iteration.

The heuristics for second screen applications conclude the materials to support the user-centered design process for a satisfying second screen experience presented in this work. These results are discussed together with the other contributions in this work in the final chapter, which also provides an outlook on the future work in the context of second screen applications.

Part IV – Conclusion

10 Conclusion

10.1 Summary and Contributions

This dissertation has addressed different aspects concerning second screen interaction and applications separated in three parts: a theoretical background, a technical implementation, and results from empirical and explorative studies to improve second screen interaction. The main contributions of each part are summarized and discussed in this chapter, followed by outlining approaches for future work.

10.1.1 Background Second Screen

Summary

Chapter 2 presents a unified definition for second screening based on a structured review of literature of 65 sources and a market analysis of currently available second screen applications. The thereby identified aspects associated with the term second screen were then discussed and resulted in five essential characteristics: the inclusion of any screened device as potential first and second screen, the possible consumption of any kind of media content, the necessary physical separation of both devices, their simultaneous use, as well as the reference of each additional device as second screen. These criteria clearly delimit the term second screen in contrast to the prior inconsistent use in literature, which also states the motivation for this chapter.

In addition, insights regarding second screen activity and dedicated applications were retrieved from literature, which helped to shape the understanding of the nature of second screening. Although there are discrepancies in the exact numbers, it has been repeatedly confirmed that second screening is a widespread activity with many different possibilities of application. This high distribution of second screen activity was confirmed by the studies conducted in this work, of which the results are presented in Chapter 2.

Furthermore, the content-related ISGCO classification and a technical classification were presented to improve the understanding of the different benefits

and implementation possibilities of second screen applications, created on basis of a review of literature and a market analysis.

Essentially, Chapter 2 offers a comprehensive illumination of the concept second screen and its characteristics, as well as a reflection on the current state of the related literature. The definition of the term and its characteristics provided here are therefore an important basis for this dissertation.

Discussion

Although second screen behavior and dedicated applications have been the subject of a multitude of studies over the last two decades, the term used is only rarely explicitly explained. If a clarification is provided, in most cases it consist of an example of the main use case of second screening, e.g. the parallel use of television content and mobile devices, rather than a comprehensive definition and delimitation. It is remarkable how such a common activity as second screening can be covered by so much literature without the emergence of a clear common understanding, or at least a discussion towards it. Therefore, these aspects are covered by this dissertation: a clear description of what is understood as second screening, which activities are included, and how these are currently realized. Future work in this area can use these contributions to position their research activity and thus facilitate communication. The contributions provided here can also be discussed in this context or be adapted to future developments, which nonetheless serves the purpose of this chapter: a progression of the discussion concerning the term second screen towards a uniform understanding.

Contributions

- Overview on the current state of the art in literature regarding second screen.
- Reasoned delimitation of the term second screen and its characteristics.
- Content-related ISGCO classification of the benefits provided by second screens.
- Technical classification on different implementation approaches of second screen application in relation to general second screen activity.
- Assessment of second screen behavior found in studies conducted in this work.

10.1.2 Multi-Platform 2ndS SDK

Summary

Chapter 3 covers the theoretical background for the development of the 2ndS SDK beyond the scope of second screening, which was comprehensively addressed in the previous chapter, as it states the main topic of this dissertation. Two further topic areas are examined in this context: *cross-platform software development* and *design science research*.

Cross-platform development is the approach to support multiple software platforms with the same code basis. These approaches emerge from the desire to reduce the development and maintenance effort for applications caused by the redundant implementation towards different platforms in the same domain, but are associated with certain drawbacks compared to native solutions. The reflection of the relevant literature in this regard is important, since the 2ndS SDK is a cross-platform solution and many insights have been gained to improve its quality in this all but new field of research. The development of the 2ndS SDK itself was structured by the *design science research* process model of Vaishnavi and Kuechler (2015) to ensure the reliability and quality of the outcome. The general concept of design science as research procedure, its delimitation to other fields of

research, and the selection of the process model with the help of the relevant literature is covered by Chapter 3.

Chapter 4 contains the development of the 2ndS SDK with the associated steps according to the applied design science research model. In this process, the addressed problem was described in detail by means of an analysis of the current situation in the development of second screen applications. Subsequently, the 2ndS SDK was proposed as a suggestion, for which concrete functional and non-functional requirements were collected, specified, and prioritized on basis of the analysis previously carried out and with additions from literature. The development of the SDK consisted of multiple iterations, which were carried out parallel to the development of prototypes to ensure the functionality of the outcome. Limitations of essential libraries, protocols, or platform specific characteristics could not be overcome by this approach, as the SDK does not constitute an entirely new solution, but rather optimizes the existing approaches to reduce the workload on developers. The final 2ndS SDK was evaluated by means of test applications for Android and the three first screen layers, in which differences between the layers were found, but overall the SDK was assessed as reliable and performant. Altogether, all previously defined requirements were met and the SDK was found to be satisfactory.

Within the scope of this dissertation several functional prototypes were created, which is presented in Chapter 5. These prototypes were built to examine either individual parts or the entirety of the 2ndS SDK, or to explore novel second screen interaction concepts. Furthermore, these prototypes demonstrated that the created SDK is functional and capable to address the underlying problem of the double multi-platform problem in the development of second screen applications.

Discussion

The analyzed literature on cross-platform development indicates that these approaches are not able to provide a completely satisfying solution to the underlying problem of platform heterogeneity in different domains. However, in most

cases the problem seems to lose relevance over time as one or two platforms prevail over the others, as with Microsoft Windows and macOS, Android and iOS, or Chrome and Firefox. A similar process is expected to happen in the field of first screen platforms, but even if only two platforms remain, the double multi-platform problem remains existent in this context, as neither Android nor iOS are likely to disappear completely in the near future. The here introduced 2ndS SDK does also not attempt to solve the problem of redundant development of the corresponding first and second screen application parts itself, of which many different approaches exist with currently no ideal solution. The 2ndS SDK addresses the problems created by the availability of multiple platforms on both the first and second screen side and the thereby multiplied increased development effort for connecting these parts. The connection between two first and two second screen platforms results in fourfold implementation, of which the 2ndS SDK is able to remove the multiplication factor. The evaluation of the SDK shows, that the here applied cross-platform approach is able to produce satisfying results, also in terms of the often criticized performance. However, the functionality provided here represents a completely different scope compared to cross-platform approaches for entire applications, and is therefore not entirely comparable. Nevertheless, the 2ndS SDK provides an improvement of the current situation in the development of second screen applications and is expected to remain relevant, as it is currently unlikely for a unified solution to emerge.

Contributions

- Review and synthesis of related work on cross-platform development and design science research.
- Design, development, and evaluation of the 2ndS SDK, which is assessed as satisfying solution for addressing the multi-platform problem in the development of second screen applications.
- Introduction of several functional second screen application prototypes, which prove the functionality of the 2ndS SDK and explore novel use cases in this context.

10.1.3 Creating a Satisfying Second Screen Interaction

Summary

The third part of this dissertation focusses on generating insights on how to design second screen interaction beyond the technical scope. The thereby generated results are intended to be used at the different phases of a human-centered design process.

The application components (cf. Chapter 6) raised and validated in a mixed-methods approach show the versatile application scenarios of second screen features. The presented collection of 55 components, classified according to the IS-GCO classification, and the instructions on how to apply them aim to inspire the design of second screen applications that represent a useful extension adapted to the targeted context of use.

Two sets of guidelines are presented for the actual production of the design solution: recommendations on the direction of attention (cf. Chapter 7) and general design guidelines (cf. Chapter 8). Regarding the direction of attention, two eye-tracking studies were conducted that found that the major part of attention is focused on the first screen and that the notifications used and information presented must be adapted to the current content. Concrete recommendations are given for this purpose, which can be taken into account during development. The same applies to the general design guidelines, which were created based on existing guidelines and concepts established in available applications, and evaluated in a user test in order to provide reasoned recommendations.

For the evaluation of the second screen application in development, heuristics were derived in a research-based approach and extended to a heuristic checklist to facilitate their use (cf. Chapter 9). The aim of this approach is to effectively identify common usability problems with the current application, before actual users encounter them. In an evaluation with experts and a user test, the developed heuristics were assessed to be satisfactory.

Discussion

Each development process, as well as their outcomes, are very individual and therefore hard to generalize, especially with rather new use cases such as second screen applications. The third part of this dissertation presents proposals for addressing reoccurring problems in this process, such as the selection of features to implement, how to direct attention, how to design the application, and aid for effectively identifying common problems.

The application components presented are to be seen as an extensible collection of potential second screen benefits and as profile of the current landscape. The overall completeness of the collection is difficult to assess. Although it has been created as comprehensively as possible, it cannot be ruled out that further aspects exist, that could not be captured. However, these can effortlessly be added to the created structure. Furthermore, it was shown that most applications tend to use the same features, e.g. the display of information and control aspects, which are comprehensively illuminated in the collection presented.

The sample of the survey validating the usage of the components regarding different genres and program types was rather low and therefore less generalizable. The findings nevertheless fulfill their purpose, as they confirm previous, but less thorough studies in this area. Overall, the aim of the collection presented is to inspire the implementation of more innovative features and reflect on their suitability in certain contexts, as well as to show the versatility of second screens. The problem of transferability of laboratory studies to natural behavior is a limitation that is difficult to overcome in many studies, but the results are valuable nonetheless. These results provide a concrete approach for the design of second screen applications and future studies on the subject. There is also no pattern solution for this desired complementary design, but a series of smaller aspects that should be considered, which are provided in this work. The resulting structure and standardization again serves the goal of systematically progressing second screen applications, also beyond laboratory settings.

The same principle applies to the introduced design guidelines, which are to be understood as a basis describing the most important aspects of a second screen

interaction. These do not have to be implemented one-to-one in future applications, but rather should be adopted and rearranged in order to create novel solutions while maintaining the essential parts. This represents a special area of tension, since functionality and usability must be given, but also creative design paths have to be found, sometimes breaking with conventional patterns (Malaka et al., 2009, p. 400).

The adaptation of heuristics to different domains seems almost common practice in this field of research, but the verification of the generated results needs to be included more often in this process, as discussed in the associated chapter. The presented validation of the heuristics for second screen applications states a first step towards this process, which can be extended by further iterations. The concept of heuristics as a checklist was very well received in the evaluation, as the mixed form of free and guided evaluation proved very efficient. This concept seems worth further evaluation in general and could be transferred to other domains than second screening.

Contributions

- Collection of 55 application components for second screen applications with application examples and instructions.
- Insights in the attention behavior during second screen activity and recommendations on how to design the guidance of attention.
- Design guidelines with reasoned recommendations of the most important aspects of second screen interaction.
- Heuristics in checklist form for the efficient identification of common problems in second screen applications.

10.2 Outlook and Future Work

This dissertation provides a comprehensive illumination of second screen applications. One goal is to standardize the currently existing but often scattered concepts. The definition and classifications provided here, aim ease the positioning of new research in this field and thereby facilitate communication. The guidelines and design recommendations are intended to contribute to the development of a uniform and comprehensive interaction concept. However, these results are only the beginning of this process, as many results can be validated to a larger extend. Future work should not only test the results presented here, but also keep developing them by further revision and improvement through feedback. This applies in particular to the overall concept of the heuristics as checklist, which has so far been covered little by existing literature.

The first screen layers supported by the *2ndS SDK* cover a wide distribution of currently available platforms. To adapt to future developments on the first screen market, additional layers can be added into the existing structure as needed. The best prospects for the advance of second screen applications would be the introduction of a new unified solution supported by all relevant first screen manufacturers, which includes all the discussed basic requirements, e.g. discovery, launch, and communication. However, this seems unlikely to enter the market at present, as the prior approaches in this direction were either not fully functional, deprecated, or not supported by all necessary platforms. This is still the same initial situation as of the start of this dissertation, and has not changed in other domains for a long time.

Finally, the results from this dissertation cannot only be the basis for new research and development processes in the field of second screening, but can also be transferred to other fields of application. The link between different types of devices is likely to increase in the future, and many parallels can be drawn with second screen applications, especially in the display of information and control aspects. Mobile devices are becoming an increasingly important part in human-computer interaction, and have the potential to become the personal link to a multitude of devices, similar to second screen applications.

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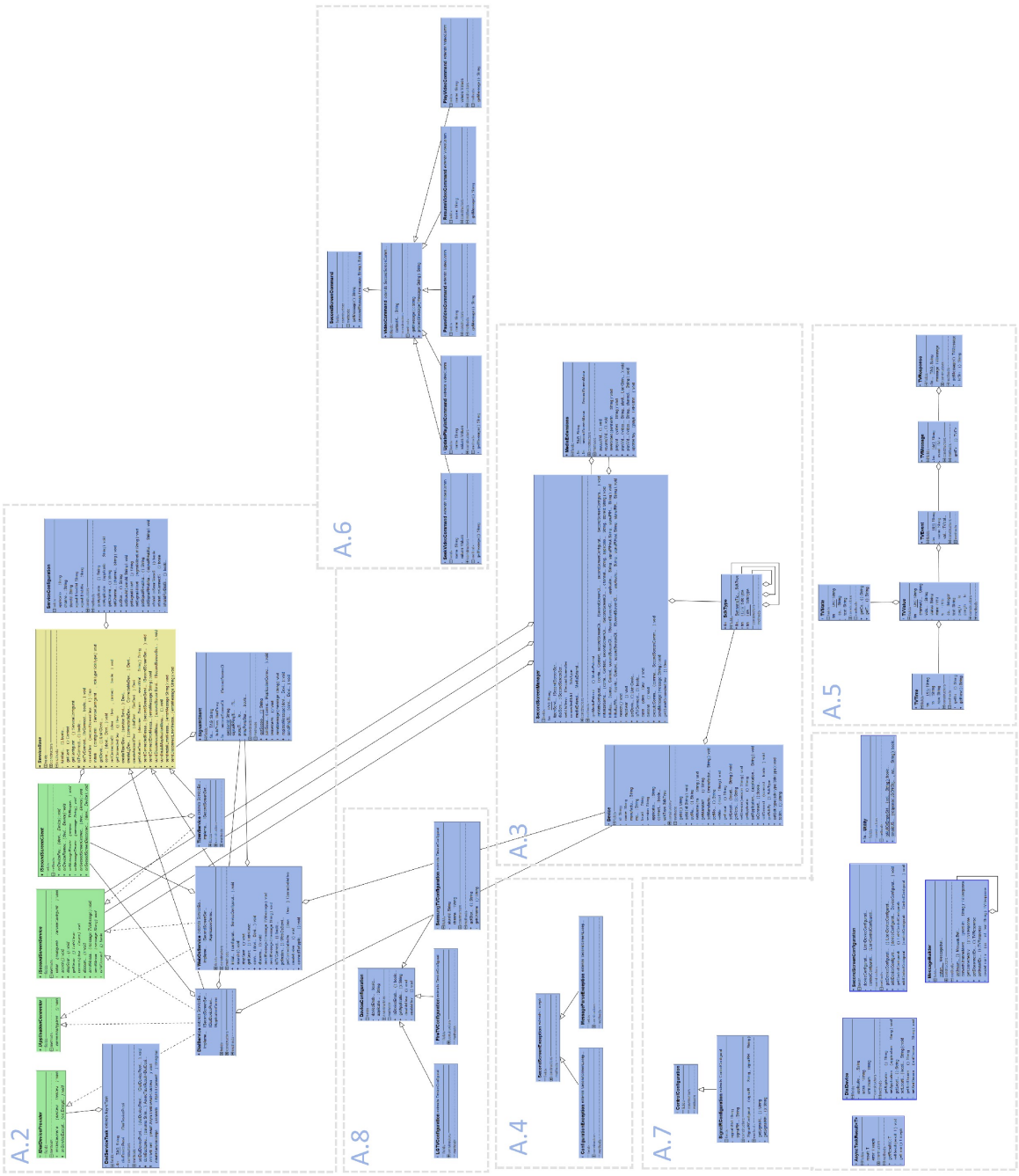
Appendices

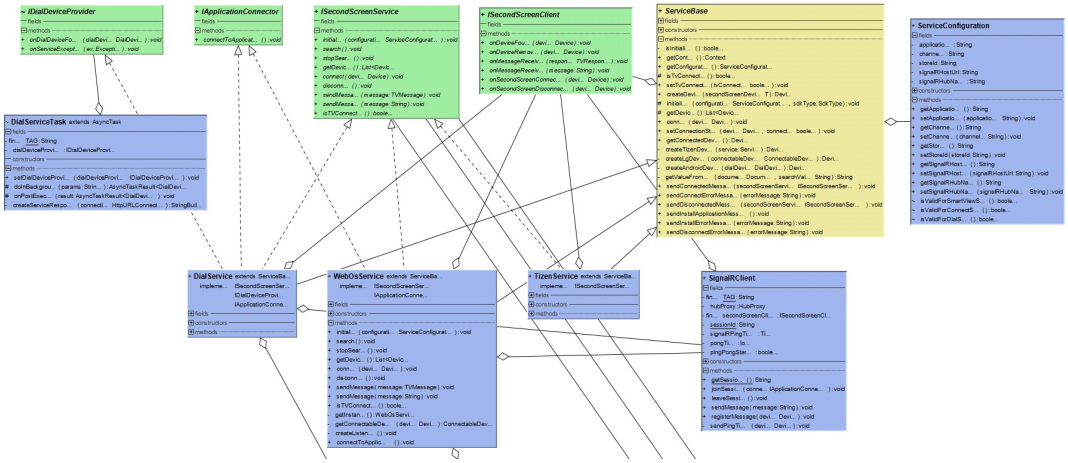
A. Architecture Multi-Platform Second Screen SDK

This appendix provides a total overview on the architecture of the 2ndS SDK with the help of UML diagrams. First, a complete view if given, and in the following the single aspects in more detail. All data in the appendix, including the UML diagrams of the 2ndS SDK, can also be found in the digital appendix.

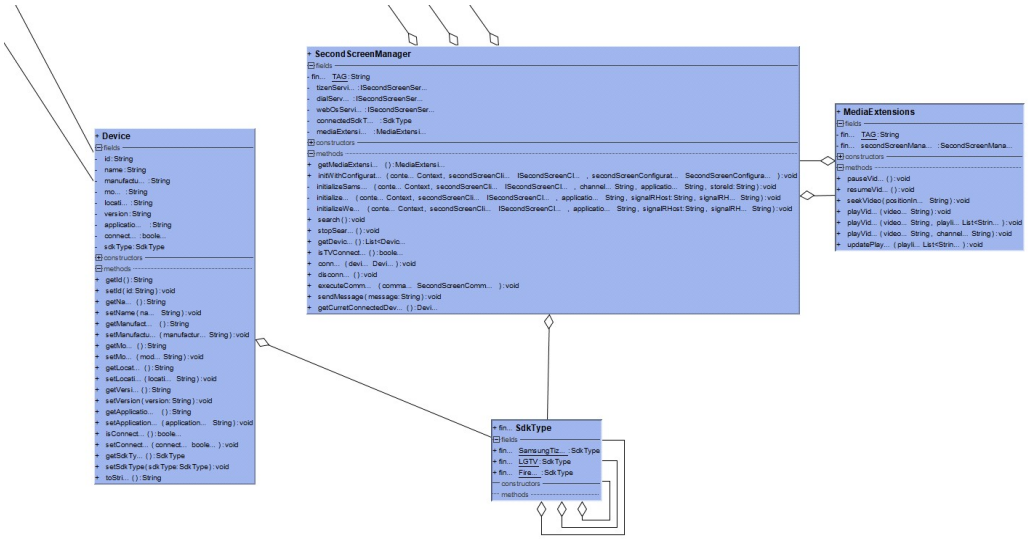
A.1 Total UML Diagram of the 2ndS SDK



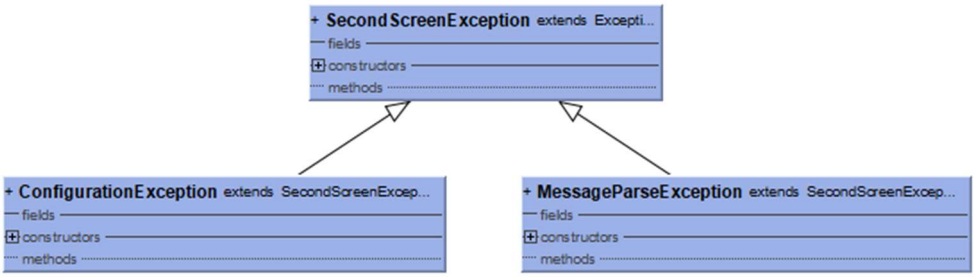
A.2 UML Diagram Second Screen Services



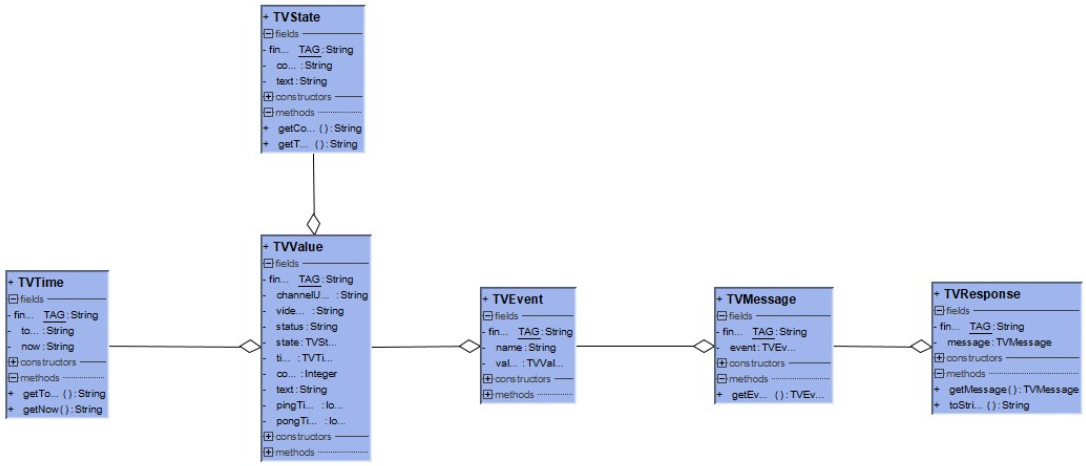
A.3 UML Diagram Second Screen Manager



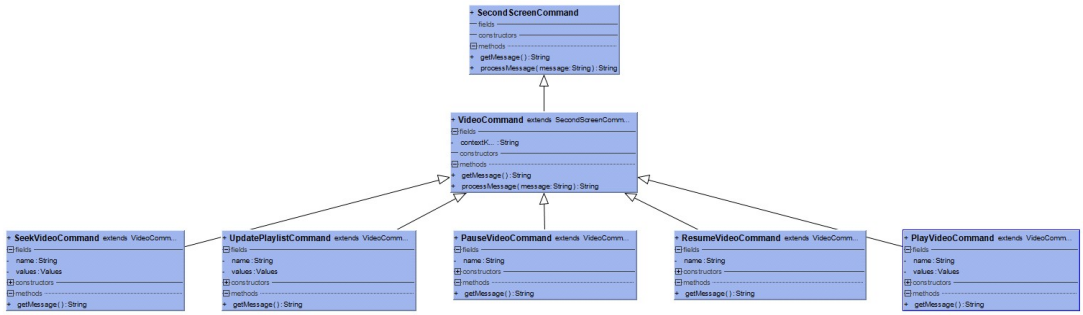
A.4 UML Diagram Second Screen Exceptions



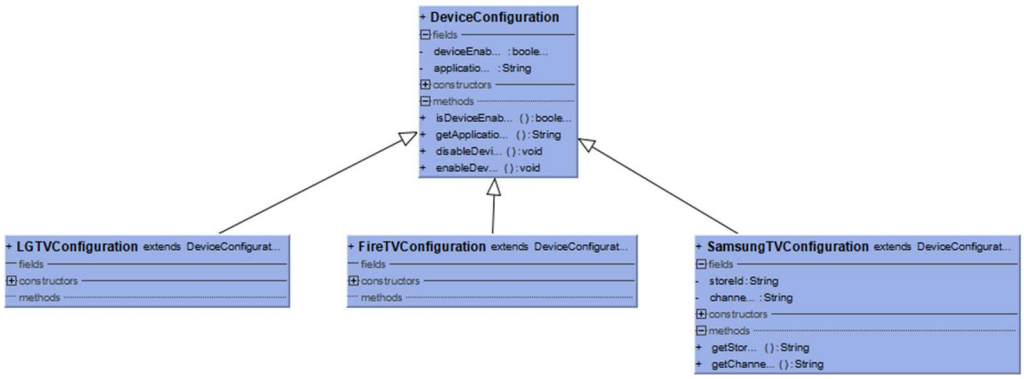
A.5 UML Diagram Second Screen TV States



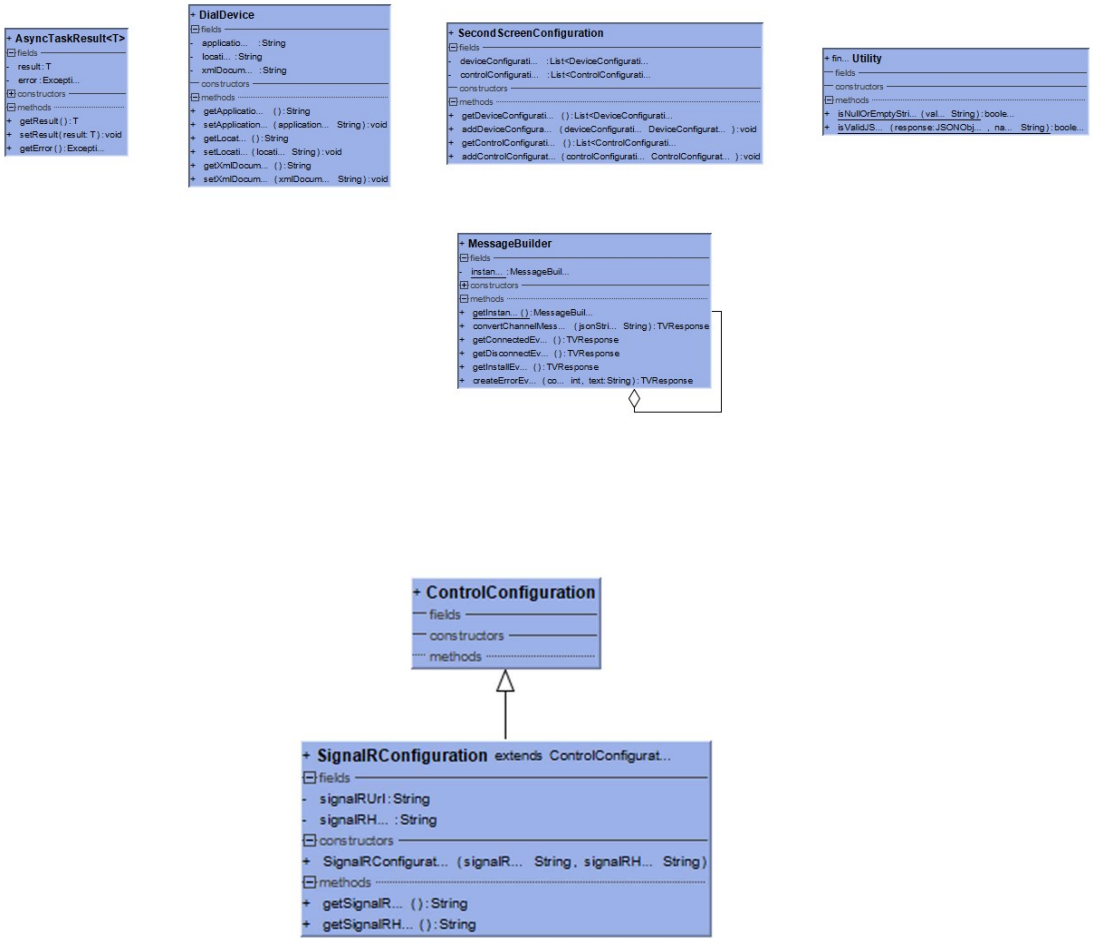
A.6 UML Diagram Second Screen Commands



A.7 UML Diagram Device Configuration



A.8 UML Diagram Second Screen Helper Classes



B. Survey Livestream Interaction

All material presented in the following was created in collaboration with Bernhard Schweiger as part of her master's thesis, supervised by the author (cf. Chapter 5.3).

B.1 Survey Current Use Gaming Streams

Fragebogen zur Nutzung von Gaming-Live-Streams

Vielen Dank, dass du dir die Zeit zur Beantwortung meines Fragebogen nimmst! :)

Du kennst mich wohl als "DerHansus" oder Bourney. Mein richtiger Vorname lautet Bernhard und ich studiere an der Universität Regensburg Medieninformatik und schreibe nun meine Abschlussarbeit für den Bachelor.
In meiner Arbeit geht es darum Streamern mehr Möglichkeiten zur Interaktion mit ihrem Publikum an die Hand zu geben. Es soll das Konzept einer App für das Handy erforscht werden, die während dem Streaming weitere Kommunikationsmöglichkeiten zwischen Streamer und Nutzer bereithält.

Du konsumierst mit großer Wahrscheinlichkeit zumindest hin und wieder Live-Streams von oder zu verschiedenen Videospielen. Damit bist du perfekt zur Beantwortung der Fragen geeignet!

Ich bitte in jedem Fall um ehrliche und ernsthafte Antworten. Außerdem gibt es kein "richtig" sowie "falsch".

Dieser Fragebogen ist vollkommen anonym.

Nochmal vielen Dank für deine Hilfe und los geht's! :D

* Erforderlich

Alter *

Meine Antwort

Geschlecht *

- ○ Weiblich
- ○ Männlich

Beruf (Schüler, Student, ...) *

Meine Antwort

Wie oft konsumierst du Gaming-Live-Streams?

- ○ Nie
- ○ Einmal im Monat
- ○ Einmal in der Woche
- ○ 2 bis 6 mal in der Woche
- ○ Einmal Täglich
- ○ Mehrmals Täglich

Wie lange konsumierst du Gaming-Live-Streams durchschnittlich am Stück?

Std. Min. Sek.

: :

Auf welchem Gerät konsumierst du Gaming-Live-Streams?

- ☐ Handy
- ☐ Tablet
- ☐ PC
- ☐ TV
- ☐ Anderes Gerät

Benutzt du ein zweites Gerät (z.B. Handy) während dem Anschauen eines Streams?

- ○ Ja, fast die ganze Zeit
- ○ Ja, aber eher selten
- ○ Nein, nie

Interagierst du während dem Zusehen mit dem Streamer zum Beispiel via Chat?

- ○ Ja
- ○ Nein

Wünschst du dir mehr oder weniger Interaktion zwischen dir und dem Streamer?

	1	2	3	4	5	
Deutlich Weniger	○	○	○	○	○	Deutlich Mehr

WEITER

Fragebogen zur Nutzung von Gaming-Live-Streams

Bewerte die nachfolgenden zusätzlichen Möglichkeiten zur Interaktion mit dem Streamer während dem Stream auf einer Skala von 1 bis 5 in ihrer Wichtigkeit!

Teilnahme an Umfragen

	1	2	3	4	5	
sehr unwichtig	○	○	○	○	○	sehr wichtig

Beantwortung einzelner, expliziter Fragen des Streamers durch Kommentare

	1	2	3	4	5	
sehr unwichtig	○	○	○	○	○	sehr wichtig

Teilnahme an Losungen/Gewinnspielen

	1	2	3	4	5	
sehr unwichtig	○	○	○	○	○	sehr wichtig

Minispiele

	1	2	3	4	5	
sehr unwichtig	○	○	○	○	○	sehr wichtig

Stream-Währung (Verdienst der Währung durch Schauen des Streams, Einsetzen für Vorteile)

	1	2	3	4	5	
sehr unwichtig	○	○	○	○	○	sehr wichtig

Beste Stellen im Stream eintragen

	1	2	3	4	5	
sehr unwichtig	○	○	○	○	○	sehr wichtig

Liste der Top-Zuschauer, -Chatter etc.

	1	2	3	4	5	
sehr unwichtig	○	○	○	○	○	sehr wichtig

Welche andere Art der Interaktion fehlt dir oder würdest du dir wünschen?

Meine Antwort

B.2 Evaluation Enhanced Livestream Interaction

Fragebogen zum Live-Test

Vielen Dank, dass du dir die Zeit zur Beantwortung dieses Fragebogen nimmst! :)

Du warst bei Schlappis Live-Stream dabei und hast die Handy-App aktiv genutzt? Dann bist du für diesen Fragebogen geeignet!

Du kennst mich wohl als "DerHansus" oder Bourney. Mein richtiger Vorname lautet Bernhard und ich studiere an der Universität Regensburg Medieninformatik und schreibe nun meine Abschlussarbeit für den Bachelor.
In meiner Arbeit geht es darum Streamern mehr Möglichkeiten zur Interaktion mit ihrem Publikum an die Hand zu geben. Es soll das Konzept einer App für das Handy erforscht werden, die während dem Streaming weitere Kommunikationsmöglichkeiten zwischen Streamer und Nutzer bereithält.

Ich bitte in jedem Fall um ehrliche und ernsthafte Antworten. Außerdem gibt es kein "richtig" sowie "falsch".

Dieser Fragebogen ist vollkommen anonym.

Nochmal vielen Dank für deine Hilfe und los geht's! :D

* Erforderlich

1. **Alter** *

2. **Geschlecht** *
   Markieren Sie nur ein Oval.
   - ◯ Männlich
   - ◯ Weiblich

3. **Beruf** *

4. **Hast du die App auf dem selben Gerät bedient auf dem du auch den Stream geschaut hast?**
   Markieren Sie nur ein Oval.
   - ◯ Ja
   - ◯ Nein

5. **Wie hat dir die Nutzung der App gefallen?**
   Markieren Sie nur ein Oval.

	1	2	3	4	5	
Sehr schlecht	◯	◯	◯	◯	◯	Sehr gut

6. **Wie beteiligt im Stream hast du dich durch die App gefühlt?**
Markieren Sie nur ein Oval.

	1	2	3	4	5	
Deutlich weniger als sonst	◯	◯	◯	◯	◯	Deutlich mehr als sonst

7. **Wie hat es sich auf deine Kommunikation mit dem Streamer ausgewirkt?**
Markieren Sie nur ein Oval.

	1	2	3	4	5	
Deutlich verschlechtert	◯	◯	◯	◯	◯	Deutlich verbessert

8. **Hattest du durch das Verwenden der App das Gefühl von Einfluss auf das Geschehen im Stream?**
Markieren Sie nur ein Oval.

	1	2	3	4	5	
Nein, gar nicht	◯	◯	◯	◯	◯	Ja, sehr

9. **Was sollte man bei der App noch verbessern/verändern?**

C. Mixed Methods Study Application Components

All material presented in the following were created in collaboration with Eva-Maria Meier as part of her master's thesis, supervised by the author (cf. Chapter 7.2).

C.1 Cultural Probe

C.1.1 Introduction

Liebe Probandin, lieber Proband,

im Rahmen meiner Masterarbeit im Fach Medieninformatik an der Universität Regensburg möchte ich die Second Screen Nutzung beim Fernsehen erforschen, um Anwendungsszenarien zu erheben. Die Teilnahme an dieser Cultural Probe erfolgt anonym. Falls Sie eine Frage zu einer Aufgabe haben, zögern Sie nicht diese mir zu stellen.

In diesem Paket werden zwei Arten von Aufgaben bereitgestellt. Aufgaben die zu einem bestimmten Zeitpunkt erledigt werden müssen und Aufgaben die du erledigen kannst, wenn du gerade Zeit hast.

Aufgaben zu einem Zeitpunkt:	**Aufgaben wann immer du Zeit hast:**
• Der Steckbrief → Am Anfang des Testzeitraums. • Das Tagebuch → Immer wenn du den Fernseher anschaltest. • Die Werbung → Wenn gerade Werbung kommt.	• Das Foto-Shooting • Deine Fernsehgewohnheiten • Party-Time • Das Sticker-Buch • Die Ideen - Fabrik

Bitte versuche alle Aufgaben vollständig zu bearbeiten. Vielen Dank, für deine Teilnahme!

C.1.2 Profile

Mein Steckbrief

Ich bin (weiblich / männlich) _____

Ich bin _____ Jahre alt.

In meinem Haushalt leben außer mir noch _____ Personen.

Mein höchster Bildungsabschluss ist: _____

Ich bin _____ von Beruf.

Meine Lieblingsshows / - serien sind: _____

_____

_____

Was ich mir unbedingt nächste Woche am Fernsehen ansehen möchte ist: _____

_____

Ich schaue aktuell Fernsehen, weil: _____

_____

Ich schaue am liebsten Fernsehen (Alleine, mit Freund usw.) _____

_____

Wenn ich an Fernsehen denke, dann denke ich sofort an: _____

_____

_____

Welche Medientechnologien (Receiver, Apple TV, Amazon Fire Stick usw.) und -programme (Netflix, Amazon, Maxdome) nutzt du in Verbindung mit Fernsehen?

_____

_____

_____

C.1.3 Diary

Ich habe während des Fernsehens folgende Dinge gemacht:

Wenn du während des Fernsehens ein mobiles Gerät (Smartphone, Laptop usw.) in der Hand hattest, notiere **warum** du es in die Hand genommen hast und **was** du dann am mobilen Gerät **gemacht** hast.

z.B.: Mein Handy hat geblinkt → ich habe meine Nachrichten gelesen.

Ende des Fernsehens

Wann hast du den Fernseher ausgeschaltet und warum?

Beginn Fernsehen:

Datum

Uhrzeit

Ich schaue gerade: _____

Ich habe den Fernseher eingeschaltet, weil: _____

Ich sehe gerade Fernsehen mit:

- ☐ Niemanden
- ☐ Meinen Partner
- ☐ Mit einem Freund
- ☐ Mit Freunden
- ☐ Mit meiner Familie
- ☐ _____

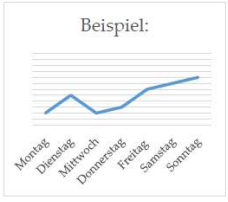
Während des Fernsehens:

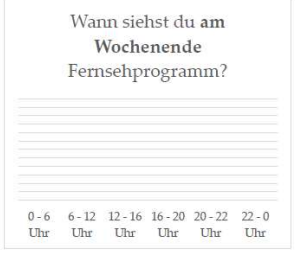
Wie oft nehme ich das Smartphone, Tablet, Laptop in die Hand: (Erstelle eine Strichliste)

C.1.4 Viewing Habits

Meine Fernsehgewohnheiten

Bitte zeichne hier ein, wann du im Durchschnitt Fernsehprogramm ansiehst. Es muss nicht für die aktuelle Woche eingezeichnet werden.





C.1.5 Sticker Book

In dieser Aufgabe geht es darum, zu erfahren welche Produkte du rund um den Fernseher nutzt.

Für diese Aufgabe wurden dir dieses Heft und Sticker gegeben. Bitte klebe die Sticker immer auf deine Antworten oder in den blauen Kreis.

Bei manchen Aufgaben kann man auch mehrere Antworten mit Stickern versehen.

Diese Aufgabe kann in den bei den meisten Aufgaben von mehreren Personen beantwortet werden, wenn das gewünscht ist. So kann beispielsweise bei der ersten Aufgabe pro Person im Haushalt ein Sticker geklebt werden. Bitte beschriftet in diesem Fall die Sticker mit verschiedenen Initialen (A/B).

Ich probiere neue technische Geräte gerne aus:

Ich versuche immer, die neusten technischen Geräte zu besitzen:

Ich kenne mich mit technischen Geräten gut aus:

Ich nutze als Video on Demand oder Video Stream Service:

Sonstiges

Bitte nenne den Services: _____

Welche Medien nutzt du beim Fernsehen?

- DVD
- Video on Demand
- Mediatheken
- Fernsehprogramm

In meinem Haushalt gibt es folgende Geräte zum Fernsehen oder zur Nutzung während des Fernsehens:

- Smart TV
- Tablet
- Smartphone
- Laptop
- Apple TV
- Fire TV
- Chrome Cast
- Fire Stick
- DVD Player
- Receiver
- Sonstiges _____

Welche Apps nutzt du während des Fernsehens?

Sonstiges

Bitte nenne die Apps: _____

Anmerkungen:

_____
_____
_____
_____
_____
_____

C.1.6 Photo Shooting

Bitte verwende für diese Aufgabe deine Smartphone-Kamera und sende die Bilder an den Testleiter per Whatsapp!

Diese Aufgabe soll mir zeigen, wie du am liebsten und für dich am bequemsten fernsiehst.

Schieße möglichst viele Fotos und beschreibe in einem Stichpunkt um was es sich auf dem Foto handelt, beziehungsweise zu welcher Aufgabe es gehört.

Bitte versuche die Bilder so zu machen, dass Sie möglichst der Realität entsprechen.

Alle Bilder werden nur in dieser Arbeit verwendet und nicht an andere weitergereicht.

1. Wo siehst du Fernsehen? Gibt es bei dir mehrere Fernseher? Fotografiere dein Zimmer mit dem Fernseher!
2. Wo ist dein Lieblingsplatz im Zimmer, wenn du fernsiehst?
3. Fotografiere die technischen Geräte welche mit deinem Fernseher verbunden sind!
4. Fotografiere eine typische Situation, wenn du fernsiehst. (Tisch, Sofa, vom Sofa zum Fernseher usw.)
5. Welcher Geräte brauchst du in deiner Nähe, wenn du fernsiehst?
6. Mache Screenshots, wenn du dich dabei ertappst, wenn du beim Fernsehen mit einem anderen mobilen Gerät arbeitest, liest, schreibst...
7. Fotografiere deine Lieblingsserie /-show.
8. Fotografiere alles, was im Zusammenhang mit Fernsehen bei dir noch interessant sein könnte.

C.1.7 Advertisement

Wenn gerade Werbepause bei deinem Fernsehprogramm ist……

….was machst du dann?

_____

_____

_____

…. machst du das immer, oder ist das heute eine Ausnahme?

_____

_____

_____

Welche Werbung fällt dir gerade spontan ein?

_____

Gab es schon einmal die Situation, in der du ein in der Werbung, oder Serie usw. gezeigtes Produkt interessant fandst? Worum ging es?

_____

Was hast du dann gemacht? Hast du es dir gekauft?

_____

_____

_____

C.1.8 Party Time

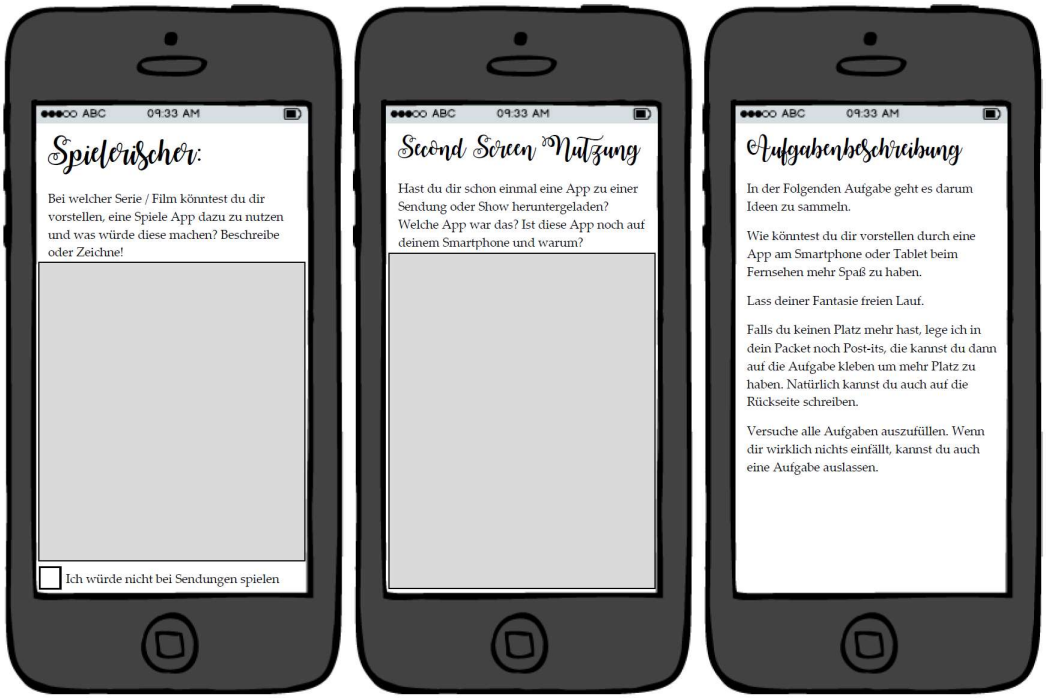
Gibt es Situationen, in denen du Freunde zum Fernsehschauen einlädst oder eingeladen wirst? Warum?

Zu welcher Serie, Show oder Film hast du das letzte Mal jemanden eingeladen?

Welche Serie, Show oder Filme siehst du dir immer mit anderen Personen an? Warum?

Warum findest du es schön Filme, Serien oder Shows mit anderen anzusehen?

C.1.9 Idea Generation



C.2 Questionnaire Validation Survey for Application Components

C.2.1 Questionnaire Validation Survey for Application Components

Umfrage zur Nutzung von Second-Screen-Anwendungskomponenten

Diese Umfrage wird im Rahmen meiner Masterarbeit an der Universität Regensburg durchgeführt.
In dieser Masterarbeit sollen Ideen für Anwendungen im Kontext Second-Screen erhoben werden. Im folgenden Fragebogen soll erhoben werden, welche möglichen Komponenten bei einer Applikation (App) in einem Sendungskontext für Nutzer, also Sie, sinnvoll sind.
Falls Sie den Begriff Second-Screen noch nicht kennen: https://de.wikipedia.org/wiki/Second_Screen

Die Teilnahme in dieser Studie ist freiwillig, deshalb beantworten Sie bitte die Fragen wahrheitsgetreu.
Die Beantwortung des Fragebogens wird ungefähr 30 Minuten dauern.
Ihre Anworten werden vertraulich behandelt und sind anonym.

* Erforderlich

Demographische Fragen

In diesem Abschnitt werden Fragen zu Ihrer Person zur späteren Auswertung der Daten gestellt.

1. **Wie alt sind Sie?** *

2. **Was ist Ihr Geschlecht?** *
   Markieren Sie nur ein Oval.
   - ◯ Weiblich
   - ◯ Männlich
   - ◯ Sonstiges: _____

3. **Wie viele Stunden sehen Sie täglich durchschnittlich Sendungen?** *
   Hierbei macht es keinen Unterschied, ob Sie linear Fernsehen, Video on Demand sehen oder Pay-TV sehen.
   Markieren Sie nur ein Oval.
   - ◯ weniger als 1 Stunde
   - ◯ 1-2 Stunden
   - ◯ 2-3 Stunden
   - ◯ 3-4 Stunden
   - ◯ 4-5 Stunden
   - ◯ mehr als 5 Stunden

Bereitschaft zur Nutzung von Second-Screen-Applikationen (App)

Falls Sie den Begriff Second-Screen noch nicht kennen: https://de.wikipedia.org/wiki/Second_Screen

4. **Nutzen Sie bereits Second-Screen-Applikationen?** *
   Markieren Sie nur ein Oval.

   ◯ Ja
   ◯ Nein
   ◯ Sonstiges: _____

5. **Würden Sie Second-Screen-Applikationen während dem Fernsehen nutzen?** *
   Hierbei ist auch das Sehen von Sendungen über Mediatheken, Video on Demand Services oder Pay-TV gemeint.
   Markieren Sie nur ein Oval.

   ◯ Ja
   ◯ Nein *Ausfüllen dieses Formulars beenden*

Motivationen beim Fernsehen und Nutzung von Second-Screen-Applikationen

6. **Wenn Sie zur Unterhaltung Fernsehen, welche Art von Second-Screen-Applikation würden Sie nutzen?** *
   Sie können auch mehrere Antworten ankreuzen.
   Wählen Sie alle zutreffenden Antworten aus.

   ☐ Informationen zur Sendung
   ☐ Soziale Interaktion zur Sendung
   ☐ Spiel zur Sendung
   ☐ Keine dieser Optionen
   ☐ Sonstiges: _____

7. **Wenn Sie entspannen beim Fernsehen, welche Art von Second-Screen-Applikation würden Sie nutzen?** *
   Wählen Sie alle zutreffenden Antworten aus.

   ☐ Informationen zur Sendung
   ☐ Soziale Interaktion zur Sendung
   ☐ Spiel zur Sendung
   ☐ Keine dieser Optionen
   ☐ Sonstiges: _____

8. **Wenn Sie mit Freunden Fernsehen, welche Art von Second-Screen-Applikation würden Sie nutzen?** *

Wählen Sie alle zutreffenden Antworten aus.

- [ ] Informationen zur Sendung
- [ ] Soziale Interaktion zur Sendung
- [ ] Spiel zur Sendung
- [ ] Keine dieser Optionen
- [ ] Sonstiges: _____

9. **Aus welcher Motivation würden Sie eine Second-Screen-Applikation nutzen?**

_____

_____

_____

_____

_____

Abhängigkeit der Anwendungskomponenten von der Sendungsart

In diesem Abschnitt möchte ich feststellen ob mögliche Komponenten einer Second-Screen-Applikation von der Sendungsart einer Sendung abhängig sind.
Sind die aufgeführten Funktionen mit Ihrer Sendung im Hinterkopf für Sie persönlich interessant und würden Sie die Komponente auch in einer Second-Screen-App nutzen?

Im Folgenden werden mehrere Sendungsarten abgefragt. Damit Sie nicht so viele Spalten haben, wurde die Aufgabe auf mehrere Fragen aufgeteilt. In der ersten Frage werden beispielsweise nur Doku, Film, Fernsehmagazin und Quiz-Show abgefragt. Weiter unten kommen noch Serien usw. Dieser Fragenblock wiederholt sich viermal.

The following questions surveyed different program types and genres in regard to different second screen components (cf. Chapter 6.4), of which one iteration is presented in the following. The presented components were queried for the genres: Fantasy, Science Fiction, Drama, Horror, Action, Mystery, Romance, Thriller, and Comedies.

The following program types were surveyed in the same manner: Casting Show, Cooking Show, Crime Show, Documentary, Game Show, Movie, News, Political Magazine, Quiz Show, Reality TV, Report, Series, Soap, Sports Report, Talk Show, and TV Magazine.

10. **Denken Sie an eine Ihnen bekannte Sendung in der unten angegebenen Sendungsart. Bestimmen Sie dann dafür welche Komponenten zur Ihrer Sendung passen würden.**

Sie können mehrere Komponenten in einer Spalte markieren, eine Komponente kann zu mehreren Sendungsarten passen. Da es ziemlich viele Anwendungskomponenten sind, empfehle ich Ihnen die Spaltennamen zu notieren, damit Sie nicht durcheinander kommen.
Wählen Sie alle zutreffenden Antworten aus.

	Doku (z.B.:ZDF History)	Film (z.B.: R.E.D.)	Fernsehmagazin (z.B.: Morgenmagazin)	Quiz-Show (z.B.: Wer wird Millionär?)
Expertenchat über die Sendung	☐	☐	☐	☐
Sozialer Chat zur Diskussion	☐	☐	☐	☐
Chat mit Freunden zur Sendung	☐	☐	☐	☐
Diskussionsforum zum weiteren Sendungsverlauf	☐	☐	☐	☐
Diskussion über Charaktere	☐	☐	☐	☐
Forum zu Fantheorien	☐	☐	☐	☐
Verlinkungen zu Soziale Netzwerk Accounts von Schauspielern der Sendung	☐	☐	☐	☐
Verlinkungen zu Soziale Netzwerk Accounts von der Sendung	☐	☐	☐	☐
Quiz zu Inhalten der Sendung	☐	☐	☐	☐
Quiz zu "Was würde der Charakter sagen...?"	☐	☐	☐	☐
Umfragen zur Bewertung der Handlung	☐	☐	☐	☐
Umfragen wer der Gewinner wird	☐	☐	☐	☐
Umfragen zur Sympathie der Darsteller	☐	☐	☐	☐
Umfragen über den Verlauf der Sendung	☐	☐	☐	☐
Beeinflussen der Sendung durch Abstimmungen	☐	☐	☐	☐
Informationen zur Lebensgeschichte des Charakters	☐	☐	☐	☐
Vorkommen des Charakters in Folge / Serie / Sendung	☐	☐	☐	☐
Verbindungen / Beziehungen der Charaktere	☐	☐	☐	☐

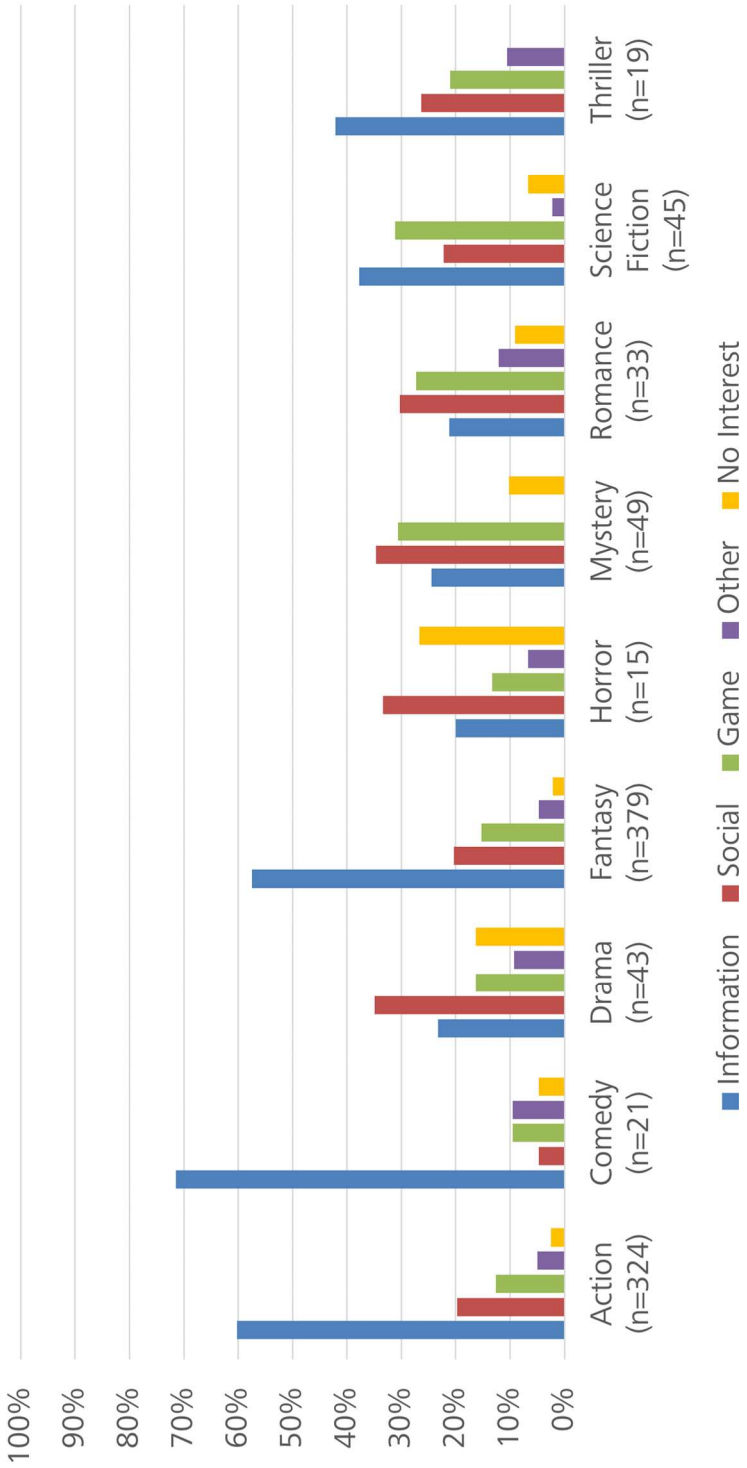
	Doku (z.B.:ZDF History)	Film (z.B.: R.E.D.)	Fernsehmagazin (z.B.: Morgenmagazin)	Quiz-Show (z.B.: Wer wird Millionär?)
Handlungsabläufe in der Sendung	☐	☐	☐	☐
Weiterführende Informationen zu den Charakter	☐	☐	☐	☐
Steckbrief des Charakters	☐	☐	☐	☐
Zusatzinformationen zu gezeigten Informationen: Musik, Drehorte, Schauspieler, Wissen, Daten und Fakten	☐	☐	☐	☐
Zusatzinformationen als Zusammenfassung der Sendung: z.B. Kleidung, Rezepte usw.	☐	☐	☐	☐
Zusatzinformationen zu ähnlichen Sendungen: Ähnliche Thematik	☐	☐	☐	☐
Zusatzinformationen zu ähnlichen Sendungen: Ähnliches Genre	☐	☐	☐	☐
Zusatzinformationen zu ähnlichen Sendungen: Nächste Folge / Serie	☐	☐	☐	☐
Zusatzinformationen zu ähnlichen Sendungen: Deine Freunde haben auch gesehen... (Bei einer Verknüpfung zu den Freunden)	☐	☐	☐	☐
Zusatzinformationen zur Sendung: Behind-The-Scene	☐	☐	☐	☐
Zusatzinformationen zur Sendung: Outtakes	☐	☐	☐	☐
Zusatzinformationen zur Sendung: Release nächste Staffel / Sendung	☐	☐	☐	☐
Timer wie lange Werbung dauert	☐	☐	☐	☐
Werbung zu in der Sendung vorkommenden Objekten	☐	☐	☐	☐
Quiz zu Sendung während der Werbepause	☐	☐	☐	☐
Videoclips der Sendung zum wiederholen von Schlüsselszenen	☐	☐	☐	☐

	Doku (z.B.:ZDF History)	Film (z.B.: R.E.D.)	Fernsehmagazin (z.B.: Morgenmagazin)	Quiz-Show (z.B.: Wer wird Millionär?)
Shopping: In Sendung vorkommende Kleidung shoppen	☐	☐	☐	☐
Keine dieser Optionen passt	☐	☐	☐	☐
Ich sehe diese Sendungsart nicht	☐	☐	☐	☐

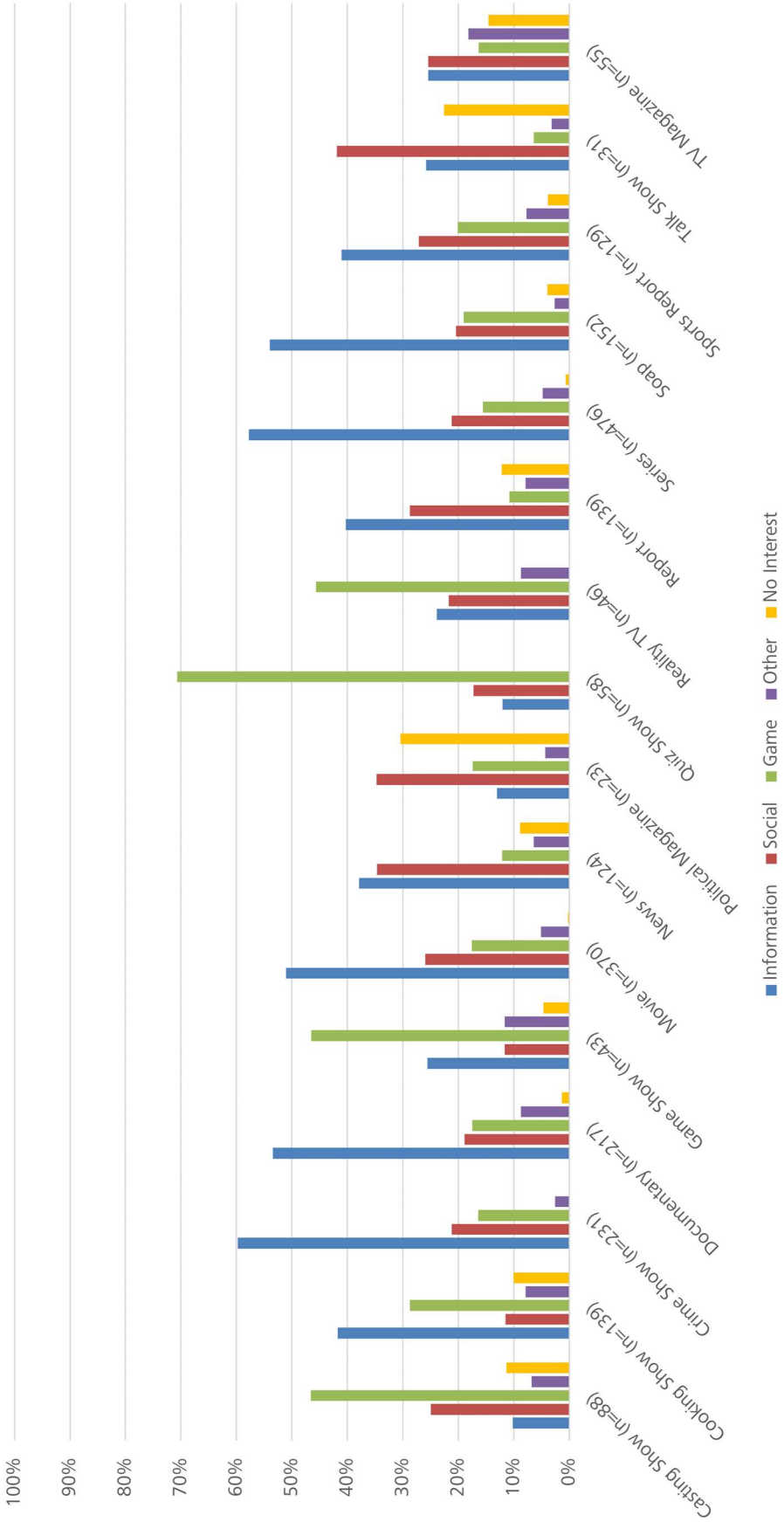
11. **Welche Sendungen haben Sie sich oben vorgestellt?** *

Nenne bitte die Sendung nach der Reihenfolge der Spalten der oberen Tabelle. (Bsp: Doku, Film, Fernsehmagazin, Quiz-Show)

C.2.2 All Results Validation Survey for Application Components



C. Mixed Methods Study Application Components

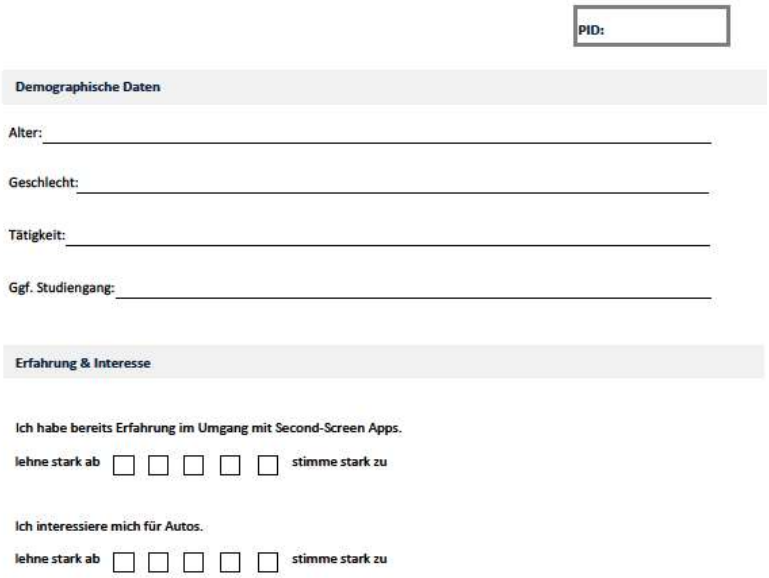


D Attention Guidance

D.1 Study Attention Towards the Second Screen

All material presented in the following was created in collaboration with Philip Eiermann as part of his bachelor's thesis, supervised by the author (cf. Chapter 7.2).

D.1.1 Demographic Questionnaire



PID:

Demographische Daten

Alter: _____

Geschlecht: _____

Tätigkeit: _____

Ggf. Studiengang: _____

Erfahrung & Interesse

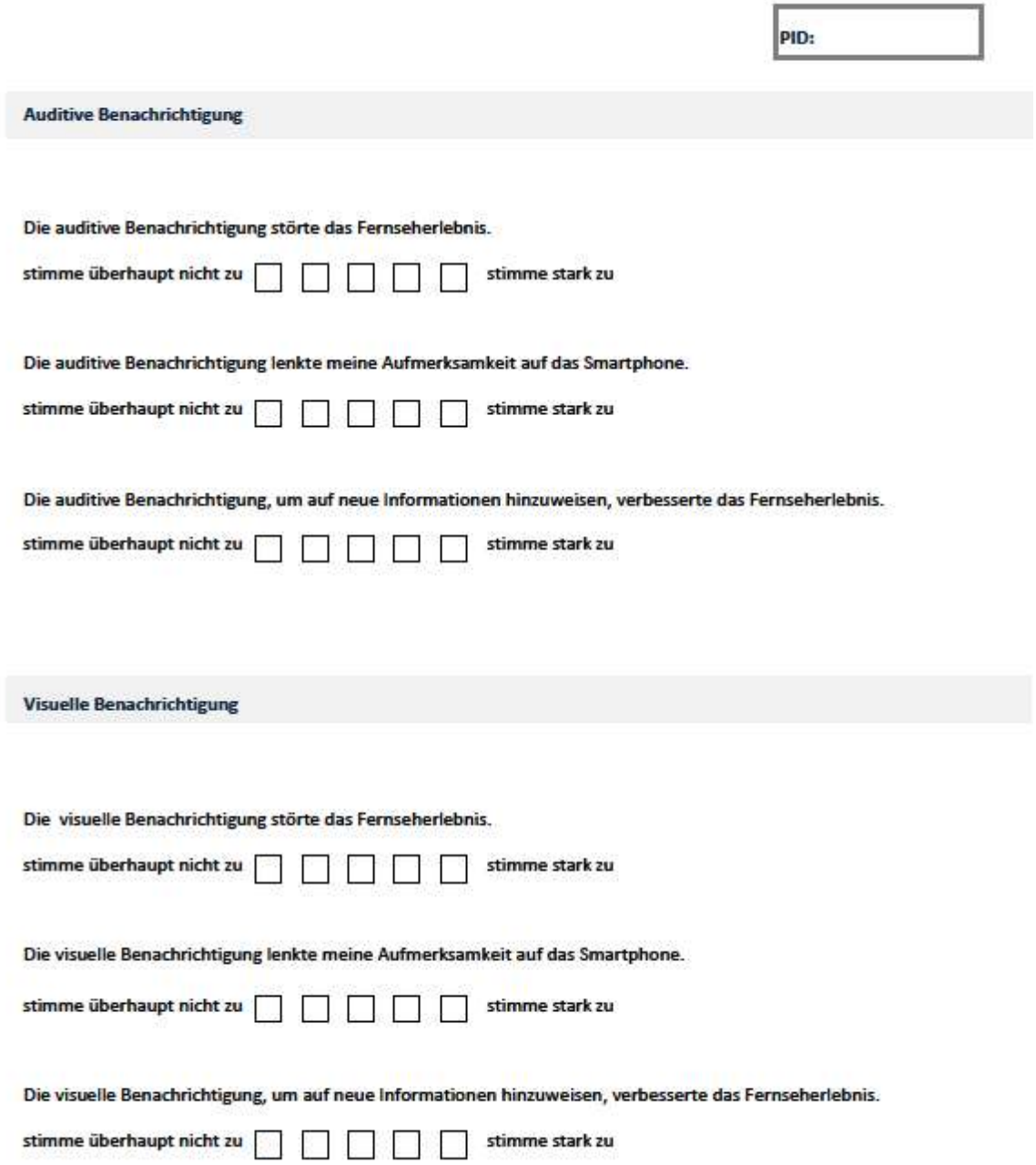
Ich habe bereits Erfahrung im Umgang mit Second-Screen Apps.

lehne stark ab ☐ ☐ ☐ ☐ ☐ stimme stark zu

Ich interessiere mich für Autos.

lehne stark ab ☐ ☐ ☐ ☐ ☐ stimme stark zu

D.1.2 Questionnaire Evaluation Notifications on the Second Screen



PID:

Auditive Benachrichtigung

Die auditive Benachrichtigung störte das Fernseherlebnis.

stimme überhaupt nicht zu ☐ ☐ ☐ ☐ ☐ stimme stark zu

Die auditive Benachrichtigung lenkte meine Aufmerksamkeit auf das Smartphone.

stimme überhaupt nicht zu ☐ ☐ ☐ ☐ ☐ stimme stark zu

Die auditive Benachrichtigung, um auf neue Informationen hinzuweisen, verbesserte das Fernseherlebnis.

stimme überhaupt nicht zu ☐ ☐ ☐ ☐ ☐ stimme stark zu

Visuelle Benachrichtigung

Die visuelle Benachrichtigung störte das Fernseherlebnis.

stimme überhaupt nicht zu ☐ ☐ ☐ ☐ ☐ stimme stark zu

Die visuelle Benachrichtigung lenkte meine Aufmerksamkeit auf das Smartphone.

stimme überhaupt nicht zu ☐ ☐ ☐ ☐ ☐ stimme stark zu

Die visuelle Benachrichtigung, um auf neue Informationen hinzuweisen, verbesserte das Fernseherlebnis.

stimme überhaupt nicht zu ☐ ☐ ☐ ☐ ☐ stimme stark zu

D.1.3 Additional Information on the Second Screen

Video Description	Notifications in Videos
Video von Audi A5 S5 Cabriolet (Länge 1:05 min)	A5 Cabriolet erhältlich ab 34.860€
	Video über A5 S5 Sportback anschauen
Video neue Dienstwagen für FC Bayern (Länge 1:46 min)	Audi ist seit 2002 Partner des FC Bayern
	Die Audi AG ist Aktionär der FC Bayern AG und besitzt 8,33% der Anteile
Eröffnung des neuen Automobilwerks Mexiko – Highlights (Länge 3:30 min)	Audi Q5 erhältlich ab 39.500€
	Erstmals entsteht ein Modell von Audi für den Weltmarkt außerhalb des europäischen Kontinents

D.2 Study Holistic Attention Guidance

All material presented in the following was created in collaboration with Peter Zeitlhöfler as part of his bachelor's thesis, supervised by the author (cf. Chapter 7.3). The video used was a twelve-minute clip from the documentary *Unsere Erde* (Tidmarsch & Fothergill, 2008), from minute 1:05:52 till 1:18:01.

D.2.1 Demographic Questionnaire

Test der Second-Screen-App

PID: _____

Beruf/Studiengang	
Alter	
Geschlecht	

1. Ich nutze mein Smartphone regelmäßig beim Fernsehen

☐ Ja

☐ Nein

2. Ich nutze mein Smartphone während des Fernsehens hauptsächlich für:

☐ Soziale Netzwerke

☐ Informationen

☐ Spiele

☐ _____

3. Ich habe bereits Erfahrung mit Second-Screen-Anwendungen:

☐ Ja

☐ Nein

D.2.2 Evaluation Concept One-Sided

Fragen zu den Zusatzinformationen

	Trifft nicht zu	Trifft eher nicht zu	unentschieden	Trifft eher zu	Trifft zu
Mir fiel es leicht beiden Inhalten zu folgen	O	O	O	O	O
Die Anzahl an Zusatzinformationen war zu wenig	O	O	O	O	O
Die Anzahl an Zusatzinformationen war zu viel	O	O	O	O	O

Nachbefragung:

PID: einfaches System

1. Findest du die Stichpunkte oder Fließtext auf dem Handy besser?

D.2.3 Evaluation Concept Divided

Fragen zu verteilten Zusatzinformationen

	Trifft nicht zu	Trifft eher nicht zu	unentschieden	Trifft eher zu	Trifft zu
Mir fiel es leicht beiden Inhalten zu folgen	O	O	O	O	O
Die Anzahl an Zusatzinformationen war zu wenig	O	O	O	O	O
Die Anzahl an Zusatzinformationen war zu viel	O	O	O	O	O

Fragen zur Rücklenkung der Aufmerksamkeit

	Trifft nicht zu	Trifft eher nicht zu	unentschieden	Trifft eher zu	Trifft zu
Eine Rücklenkung der Aufmerksamkeit ist immer sinnvoll	O	O	O	O	O
Die auditive Rücklenkung war auffällig	O	O	O	O	O
Die haptisch-visuelle Rücklenkung war auffällig	O	O	O	O	O
Die auditve Benachrichtigung ist als Rücklenkung geeignet	O	O	O	O	O
Die haptisch-visuelle Benachrichtigung ist als Rücklenkung geeignet	O	O	O	O	O

Nachbefragung:

PID: umfassendes System

1. Welche Zusatzinformationen waren dir zu viel/zu wenig? (Fernseher/Smartphone)

2. Wann findest du sie gut?

3. Findest du die Stichpunkte oder Fließtext auf dem Handy besser?

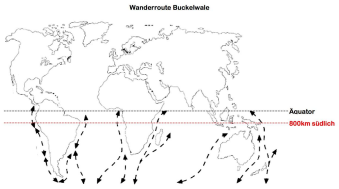
D.2.4 Additional Information Holistic Study

The additional information were presented on either the First (FS) or Second Screen (SS), depending on the tested concept (cf. Chapter 7.3.1).

Information and Source	Information	Associated Image
1. FS or SS Quelle Bild: https://de.wikipedia.org/wiki/Seehund, zuletzt aufgerufen am 27.03.2018	Pelzrobben: • Männchen ca. 1,9 Meter, 200 bis 250 kg • Weibchen ca. 1,2 Meter, 40 bis 50 kg	
2. FS or SS Quelle: http://www.frenetic.ch/schule/erde/UNSERE-ERDE_dossier.pdf, zuletzt auf-gerufen am 27.03.2018	Mutter: • Länge: 16 Meter • Gewicht: 25 Tonnen Kalb: • Länge: 5 Meter • Gewicht: 4 Tonnen	
3. SS Quelle: https://de.wikipedia.org/wiki/Buckelwal, zuletzt aufgerufen am 27.03.2018	Buckelwale: • Säugetiere • Größe: 12 bis 18 Meter • Gewicht: 25 bis 30 Tonnen • Narbengewebe durch Befall mit Seepocken Verbreitung: • In allen Ozeanen • Sommerquartiere in polaren Meeren • Winterquartiere in tropischen und subtropischen Gewässern • Fortbewegung: 1,5 bis 11 km/h, Durchschnittsgeschwindigkeit von 2 bis 5 km/h, Spitzengeschwindigkeit bis zu 27 km/h	

4. SS

Quelle: https://www.spektrum.de/lexika/images/bio/f9f6714_w.jpg, zuletzt aufgerufen am 27.03.2018



5. FS or SS

Quelle:

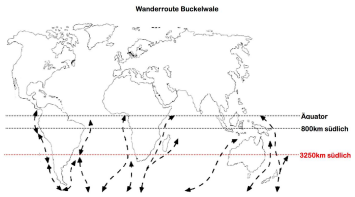
https://de.wikipedia.org/wiki/Fächerfisch, zuletzt aufgerufen am 27.03.2018

Fächerfische:
- Länge: 2,5 bis 3,8 Meter
- Gewicht: 50 bis 100kg

Geschwindigkeit:
- Neuere Studie: maximal 36 bis 45 km/h

6. SS

Quelle: https://www.spektrum.de/lexika/images/bio/f9f6714_w.jpg, zuletzt aufgerufen am 27.03.2018



7. SS

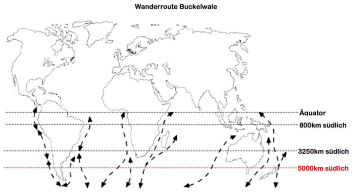
Quelle: https://de.wikipedia.org/wiki/Weißer_Hai, zuletzt aufgerufen am 27.03.2018

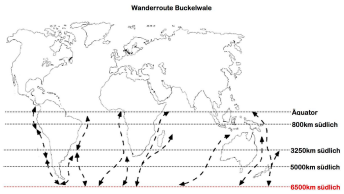
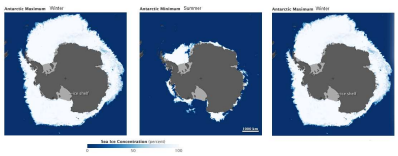
Merkmale:
- Größe: bis zu 7 Meter
- Männchen höchstens 5 Meter
- Gewicht: bis zu 3,5 Tonnen

Verbreitung:
- Beinahe weltweit in allen Ozeanen und eingewandert im Mittelmeer
- Etwa 90% entweder innerhalb von etwa 5 Metern unter der Wasser-oberfläche oder in Tiefen von 300 bis 500 Metern

8. SS

Quelle: https://www.spektrum.de/lexika/images/bio/f9f6714_w.jpg, zuletzt aufgerufen am 27.03.2018



9. FS or SS Quelle: https://de.wikipedia.org/wiki/Eisberg, zuletzt aufgerufen am 27.03.2018	Eisberge: • Etwa 90% unter der Wasseroberfläche • Drehen sich gelegentlich um	
10. SS Quelle: https://www.spektrum.de/lexika/images/bio/f9f6714_w.jpg, zuletzt aufgerufen am 27.03.2018		
11. FS or SS Quelle: http://www.frenetic.ch/schule/erde/UNSERE-ERDE_dossier.pdf, zuletzt aufgerufen am 27.03.2018	Polarsommer: • Ca. 3 Monate mit Temperaturen um 0 Grad an der Küste	
12. SS Quelle Bild: https://de.wikipedia.org/wiki/Antarktis, zuletzt aufgerufen am 27.03.2018	Antarktis Lage und Größe: • Kontinent Antarktika und südlicher Ozean (Südpolarmeer, Antarktik) • Festland Antartika Fläche 14.000.000km2 (39x Deutschland) • Offizielle Entdeckung 1820	

E Guidelines for Second Screen Applications

All material presented in the following was created in collaboration with Marcus Beck, who also conducted the analysis of existing design recommendations, as part of his bachelor's thesis, supervised by the author (cf. Chapter 8.2).

E.1 Analysis of Existing Second Screen Design Recommendations

E.1.1 Analysis Manufacturers Guidelines

Guideline	Amazon Fling	Google Cast	Samsung TV
Sender und Receiver müssen im selben Wlan Netzwerk sein	x	x	x
Status Anzeige Button	drei verschiedene Status (Kein Fire TV verfügbar, Fire TV im Netzwerk erkannt, Mit Fire TV verbunden)	vier verschiedene Status (Keine Verbindung, Chrome Cast erkannt, Stellt Verbindung her, Verbunden mit Chromecast)	/
Platzierung des Buttons im UI	Leicht erkennbar und nutzbar für den User	Cast Button muss in jedem Screen der Sender App verfügbar sein.	Bei einer App die Smart View ermöglicht, sollte der Cast Button in der rechten oberen Ecke plaziert werden.
Status: Mobiles Gerät und Emfpangsgerät sind verbunden (kein Inhalt wird abgespielt)	Mobile App zeigt den aktuellen Status des Fire TV (blau wenn verbunden, schwarz wenn nicht verbunden)	1. Antippen des Cast Buttons, zeigt den Cast Dialog 2. Receiver Name wird angezeigt 3. Cast Dialog zeigt einen Button "Stop Casting"	/
Status: Mobiles Gerät und Empfangsgerät sind verbunden (Inhalt wird abgespielt)	Mobile App zeigt den aktuellen Status des Fire TV (blau wenn verbunden, schwarz wenn nicht verbunden)	1. Cast Dialog zeigt Receiver Namen 2. Das Gerät oder der aktuellt abgespielte Inhalt wird unter dem Titel angezeigt 3. Der Button "Stop Casting" wird angezeigt	1. Wird der Cast Button angeklickt, wollte der Cast Status und die verfügbaren Optionen (Verbundener Geräte Name, Disconnect Option, usw.) angezeigt werden
Mobiles Gerät	Dient als Controller (soz. Als Fernbedienung). Inhalt sollte hier nicht angezeigt werden.	Sender App auf dem Mobilen Gerät kontrolliert ausgetrahlten Inhalt. Inhalt wird nur auf dem Empfangsgerät angezeigt	/

Guideline	Amazon Fling	Google Cast	Samsung TV
	Wenn dann in Miniaturansicht.		
Buttons	Amazon Buttons	Google Buttons	Samsung Buttons (selben wie bei Google)
Status: Mobiles Gerät und Emfpanggerät verbinden sich	/	Der Cast Button blinkt, bis einer Verbindung hergstellt wurde.	1. Der Cast Button blinkt, bis einer Verbindung hergstellt wurde 2. Wenn der Fernseher ausgeschaltet ist, schaltet er sich automatisch ein und gibt den Inhalt wieder
Status: Empfangsgerät (receiver) verfügbar	1. Fling Button zeigt Verfügbarkeit eines Fire TV an 2. Nach Antippen des Buttons wird eine Liste der verfügbaren Fire TV's angezeigt	1. Cast Button zeigt Verfügbarkeit eines Google Cast Gerätes an 2. Nach Antippen des Buttons wird Cast Dialog angezeigt 3. Cast Dialog hat den Titel "Cast to" 4. Cast Dialog zeigt eine Liste der verfügbaren Geräte an 5. Jedes Empfangsgerät sollte folgdenen Dialog anzeigen "Casting [Appname]"	1. Cast Button zeigt Verfügbarkeit eines Fernseher, welcher Smart View unterstützt 2. Wird der Cast Button geklickt, erscheint eine Liste mit den verfügbaren Geräten, die Smart View unterstützen 3. Samsung Smart TV sollte an erster Stelle der Liste sein 4. Die Liste sollte gefiltert werden, sodass nicht unterstütze Geräte, nicht angezeigt werden
Mobile App - Lautstärke Steuerung	/	Die "Sender" App muss dem Nutzer erlauben die Lautstärke, des Inhaltes auf dem Fernseher oder Lautsprecher, regeln zu können. Hierzu werden die Hardware Lautstärke Buttons oder der Software Lautstärke Regler verwendet. Die Software muss im Cast Dialog, während dem Casting angezeigt werden.	Die Hardware Buttons auf dem mobilen Gerät, sollten die Lautstärke auf dem Fernseher regeln
Mobile App - Notifications (Benachrichtigungen) *nur in Google Guidelines vorhanden	/	1. Eine Notification wird nur angezeigt, wenn die Sender App gerade nicht angezeigt wird 2. In der Statusleiste soll das App Icon und nicht das Cast Icon verwendet werden 3. In der Notification soll klar erkennbar sein welcher Inhalt wiedergegeben wird, von welchem receiver aus und grundsätzliche Steuerung (z.b.	/

Guideline	Amazon Fling	Google Cast	Samsung TV
		Play/Pause) muss möglich sein 4. Ein "X" um das Casten zu stoppen und die Verbindung zum receiver zu beenden, muss in den Aktions Möglichkeiten vorhanden sein 5. Wenn das App Logo, der Titel des Inhaltes oder die Illustration (artwork) angeklickt werden, soll sich die ausgeklappte Steuerung öffnen	
Mobile App - Sperr Bildschirm *nur in Google Guidelines vorhanden	/	1. Titel oder artwork werden angezeigt 2. Der receiver wird angezeigt (bei Musik Apps nicht nötig) 3. Wiedergabe Steuerung soll möglich sein (z.B. Play/Pause) 4. Die Lautstärke muss mit den Hardware Button zu regeln sein	/
Mobile App - Cast fortsetzen, nachdem Verbindung getrennt war	/	Eine verbundene Sender App, soll den verbundenen Status wiederherstellen, wenn implizite Verbindungsabbruch gab (z.B. Gerät schaltet sich ab, Batterie ist leer usw.) 1. Wenn ein ungeplanter Verbindungsabbruch zustande kommt, dann soll der Inhalt weiter auf dem receiver wiedergegeben werden. Wenn die App oder die Verbindung erneut gestartet wird, dann soll die App die Verbindung wieder mit dem receiver herstellen, wenn die receiver Session noch am laufen ist. 2. Der Cast Button sollte wieder in den "verbundenen Status" gesetzt werden 3. Wenn der Nutzer den Cast Button klickt, bevor erneut eine Verbindung aufgebaut wurde, wird eine Liste der verfügbaren Geräte gezeigt. Wenn der Nutzer den receiver auswählt, der gerade casted, dann soll die ausgeklappte oder die "Mini" Steuerung erscheinen	1. Die TV App behält den Status, den es vor dem Verbindungsabbruch hatte (z.B. Inhalt wird weiter wiedergegeben) 2. Die mobile App zeigt die Detailansicht und die Wiedergabe wird pausiert, während der Inhalt auf dem Fernseher weiter abgespielt wird 3. Wenn während dem Verbindunsabbruch kein Inhalt (auf dem Fernseher) abgespielt wird, bleibt die mobile App in ihrer jetzigen Ansicht
Mobile App - Cast wird gestoppt *nur in Google	/	1. Der Inhalt wird solange wiedergegeben bis, entweder der Nutzer das Casting stoppt oder	/

Guideline	Amazon Fling	Google Cast	Samsung TV
Guidelines vorhanden		die App einen neuen Inhalt casted. Wenn mehrere "Sender Geräte" mit dem gleichen receiver verbunden sind, sollte jede App einen "Disconnect" Abbruch) Button im Cast Dialog haben, anstatt des "Stop Casting" Button 2. Wenn mehrere Mobile Geräte mit einem Receiver verbunden sind und ein Sender Geärt die Verbindug trennt, dann passiert mit dem Receiver nichts und die Cast Steuerung, sowie die Benachrichtigungen werden nicht mehr auf getrennten Gerät angezeigt	
Bluetooth Low Energy (BLE) ***nur in Samsung Guidelines**	/	/	Unterstützt sowohl der Fernseher, als auch das mobile Gerät Bluetooth Low Energy (BLE), dann soll der Fernseher in der Lister der verfügbaren Geräte erscheinen, auch wenn beide Geräte nicht im selben Netzwerk sind. Wenn dieser Fernseher ausgewählt wird, soll sich der "Device Connection Guide" (Geräte Verfügbarkeits Anleitung), in einem Pop-up Fenster öffnen.
Wiedergabe Synchronsieriung zwischen mobilem Gerät und Fernseher ***nur in Samsung Guidelines vorhanden**	/	/	1.Wenn keine entsprechende App auf dem Fernsehgerät vorhanden ist, wird der Standard-Medienplayer des Fernsehgeräts zur Wiedergabe von Multimedia-Inhalten, die von einem mobilen Gerät gestreamt werden, verwendet 2. Wenn der Inhalt gelade wird, sollte auf beiden Geräten die gleiche Rückmeldung angezeigt werden (Lade Animation und Titel des Inhaltes) 3. Die Wiedergabe Steuerung sollte auf beiden Geräten angezeigt werden 4. Wenn an der Wiedergabe etwas geändert wird (z.B.

Guideline	Amazon Fling	Google Cast	Samsung TV
			Vorspulen), sollte der Wiedergabe Status auf beiden Geräten der Gleiche sein.
Multitasking - andere App wird auf dem Fernseher benutzt *nur in Samsung Guidelines	/	/	1. Die TV App bleibt aktiv im Hintergund, die Verbindung bleibt bestehen und die mobile App sollte immer noch den "Connected" Status (Verbundener Status) anzeigen 2. Solange die Verbindung besteht, muss sich die TV App in den Vordergrund schieben, wenn eine neue "Cast Request" (Cast Anfrage) von der mobilen App kommt

E.1.2 Analysis Existing Second Screen Applications

Guideline	Amazon	YouTube	Netflix
Sender und Receiver müssen im selben Wlan Netzwerk sein	stimmt nicht (kann von überall aus gestartet werden)	X	X
Status Anzeige Button	Keine Statusanzeige vorhanden	Drei veschiedene Status (Keine Verbindung, Receiver Cast erkannt, Verbunden mit Receiver)	Vier verschiedene Status (Keine Verbindung, Receiver Cast erkannt, Verbindung wird hergestellt, Verbunden mit Receiver)
Platzierung des Buttons im UI	Nur in der Detailansicht des Inhaltes	In jedem Screen vorhanden	in jedem Screen vorhanden
Status: Empfangsgerät (receiver) verfügbar	In der Detailansicht eines Filmes, Serie usw., kann der Fire TV ausgewählt werden.	Richtig bis auf Punkt 4, hier steht nur der Appname	1. Cast Dialog öffnet sich 2. Receiver kann ausgewählt werden 3. Receiver App öffnet sich (bei mehreren Nutzern muss über die Fernbedienung der jeweilige Nutzer ausgewählt werden)

Guideline	Amazon	YouTube	Netflix
UI Mobile App	1. Fling Button in der jeweiligen Detailansicht 2. Bedienelemente (Play/Pause, Vor- und Zurück spulen, Stop) sind im unteren Bereich des Screens 3. Zeitanzeige befindet sich über den Steuerelementen, neben den Steuerelementen wird vergangene und Gesamtzeit angezeit 4. Vier verschiedene Ansichten: - Szenen (Möglichkeit direkt zu einer bestimmten Szene zu springen) - In der Szene (X-Ray, die in der aktuelle Szene spielenden Schauspieler werden angezeigt) - Besetzung (Des Films/der Serie) - Musik (der jeweiligen Szene) 5. Über Menü Möglichkeit sich mit Fire TV zu verbinden	1. Richtig 2. Ja siehe "Status Anzeige" 3. Richtig (Play/Pause, Nächstes/vorheriges Video, Teilen, usw.) 4. Richtig 5. Richtig 6. Zwei Klicks: Minicontroller anklicken, Auf Titel oder Bild klicken. Also Richtig 7. Richtig 8. Minicontroller = Wiedergabeliste. Enthält geforderte Elemente	1. Cast Button in jeder Ansicht (rechts oben, nur in der Detailansicht extra Position des Buttons) 2. Detailansicht siehe Punkt 10
Buttons	Amazon Buttons	Richtig	Google Button
Status: Mobiles Gerät und Emfpanggerät verbinden sich	Ein Dialog das Mobile App und Receiver sich verbinden, gibt es nicht	Nicht Richtig, diesen Status gibt's nicht	Animation im Cast Button zeigt an, dass eine Verbindung hergestellt wird
Status: Mobiles Gerät und Emfpangsgerät sind verbunden (kein Inhalt wird abgespielt)	Geht nicht. Verbindung wird nur hergestellt, wenn Inhalt für eine Wiedergabe ausgewählt wurde	Richtig	1. Cast Dialog zeigt an das eine Verbindung besteht 2. Inhalt kann ausgewählt und über den Receiver abgespielt werden
Status: Mobiles Gerät und Empfangsgerät sind verbunden (Inhalt wird abgespielt)	1. Detailansicht der Wiedergabe öffnet sich 2. Wiedergabesteuerung siehe UI Mobile App 3. Nur Hochformat möglich auf dem mobilen Gerät in der Wiedergabesteuerung	Receiver Name, Bild, Titel, Play/Pause, Lautstärkeregler und Cast beenden	Ausgeklapptes Menü: Film/Serien Cover, Play/Pause Button, Stop Button, 30 Sek. Zurückspul Button, Sprach und Untertitel Einstellung, Cast Button, Zeitanzeige (links vergangeene Zeit, rechts noch übrige Zeit) Eingeklapptes Menü: 30 Sek. Rückspul Button, Titel, Play/Pause Button
Mobiles Gerät	Ist richtig. Inhalte werden hier nicht angezeigt.	Richtig	Steuerung über das mobile Gerät

Guideline	Amazon	YouTube	Netflix
Mobile App - Lautstärke Steuerung		Richtig	geht nicht
Mobile App - Notifications (Benachrichtigungen) *nur in Google Guidelines vorhanden	Funktioniert nur wenn App geöffnet. 1. Play/Pause Steuerung möglich 2. Mit "tipp" auf den Titel oder das Bild, wird Detailansicht der Steuerung geöffnet	1. Wird immer angezeigt 2. Cast Icon 3. Richtig 4. Richtig 5. Jeweilige letzte Ansicht in der App öffnet sich	1. wird immer angezeigt 2. Play/Pause und Stopp Button 3. 30 Sek zurückspul Button 4. Titel und Cover 5. Mit "Klick" auf Titel oder Cover, öffnet sich Detailansicht
Mobile App - Sperr Bildschirm *nur in Google Guidelines vorhanden	Funktioniert nicht. Nur wenn man sich in der App befindet.	1.Richtig 2.Richtig 3.Richtig 4. Richtig	Gleiche Ansicht wie Notification
Mobile App - Cast fortsetzen, nachdem Verbindung getrennt war	/	1.Richtig 2.Richtig 3. Richtig	Wenn Cast (vom mobilen Gerät aus) gestoppt wird, dann ist weiterhin die Steuerung des zuvor wiedergegebenen Inhalts zu sehen. Eine erneute Cast Verbindung ist erst möglich wenn, entweder in der App in eine andere Ansicht navigiert wird oder die App in den Hintergrund gelegt und anschließend wieder geöffnet wird
Bluetooth Low Energy (BLE) *nur in Samsung Guidelines	/	/	/
Wiedergabe Synchronsieriung zwischen mobilem Gerät und Fernseher *nur in Samsung Guidelines vorhanden	/	/	/
Mobile App - Cast wird gestoppt *nur in Google	/	1.Richtig 2. Richtig	1. Wenn der Inhalt gerade wiedergegeben wird, dann stoppt die Wiedergabe und die

Guideline	Amazon	YouTube	Netflix
Guidelines vorhanden			Steuerungselemente werden in der mobilen App nicht mehr angezeigt. Im Receiver wird die Detailansicht des jeweiligen abgespielten Inhalts angezeigt 2. Wenn Inhalt gestoppt ist und Verbindung getrennt wird, dann wird die Verbindung getrennt, aber Steuerung wird weiterhin angezeigt und Buttons können geklickt werden aber es hat keine Auswirkung
Multitasking - andere App wird auf dem Fernseher benutzt *nur in Samsung Guidelines	/	/	/
Kritik	1. Wenn aus der Detailansicht woanders hin navigiert wird, dann keine Möglichkeit die Wiedergabe zu pausieren, außer über die Statusleiste 2. Keine Möglichkeit während dem Streamen, andere Inhalte auszuwählen und in der eine Wiedergabeliste zu speichern 3. Wenn Wiedergabe pausiert wird und anschließend die Bildschirmsperre betätigt wird, dann kann der Nutzer den aktuell abgespielten Inhalt nicht mehr steuern und muss die Fire TV Fernbedienung verwenden oder den Inhalt über die App erneut auswählen (nur in Serien möglich in der Folgen Übersicht über Fling Button) 4. Kommunikation zwischen App und Fire TV schlecht, wird oft nicht erkannt oder als offline angezeigt 5. Reaktionszeit bis im Sperrbildschirm Wiedergabekontroller erscheint, verhältnismäßig sehr langsam		1. Oft Fehlermeldung (z.B. Zeitüberschreitung, Konfigurationsprobleme) 2. keine Lautstärkeregelung möglich über die Sender App 3. Verschiedene Vorgänge wenn Verbindung getrennt wird (siehe Cast wird gestoppt) 4. Bei mehreren Nutzern eine starten des Cast Dialogs nicht möglich (Nutzer muss mit der Fernbedienung ausgewählt werden)

E.2 Study Evaluation Guidelines

E.2.1 Evaluation Questionnaire for each Application

The following questionnaire was completed by the participants after the completion of the tasks with one of the tested applications, e.g. three times in total (cf, 8.2.3).

Test der Design Guidelines

Proband:	
Beruf/Studiengang:	
Alter:	
Geschlecht:	

1. Ich weiß was Second-Screen ist?	☐ Nein	☐ Ja
2. Ich verwende Second-Screen (parallel Nutzung Handy und Fernseher).	☐ Nein	☐ Ja
3. Ich habe schon Erfahrung mit expliziten Second-Screen-Anwendungen gesammelt	☐ Nein	☐ Ja

Wenn ja: Folgende Second-Screen Anwendungen habe ich schon benutzt.	Amazon Prime	☐
	Netflix	☐
	Youtube	☐

4. Ich besitze ein Second-Screen fähiges Gerät	☐ Nein	☐ Ja

Wenn ja: Folgende Geräte befinden sich in meinem Haushalt	Amazon Fire TV/Stick	☐
	Google Chromecast	☐
	Samsung Smart TV	☐

1. Aufgabe

Öffnen Sie die App und stellen Sie eine Verbindung mit dem Fernseher her.

Fragebogen:

	Stimme überhaupt nicht zu				Stimme vollkommen zu
1. Die gestellte Aufgabe war intuitiv lösbar.	1	2	3	4	5
2. Die gestellte Aufgabe zu lösen hat mir Probleme bereitet.	1	2	3	4	5
3. Die Anwendung hat mich strukturiert durch die Aufgabe geführt.	1	2	3	4	5
4. Die Aufgabe hat bei mir zu Frustration geführt.	1	2	3	4	5

2. Aufgabe

Sie schauen sich gerade ein Video an und schauen sich nebenbei in der App ein bisschen um. Jetzt haben Sie eine wichtige Szene verpasst. Schauen Sie sich die vorherige Szene noch mal an.

Fragebogen:

	Stimme überhaupt nicht zu				Stimme vollkommen zu
1. Die gestellte Aufgabe war intuitiv lösbar.	1	2	3	4	5
2. Die gestellte Aufgabe zu lösen hat mir Probleme bereitet.	1	2	3	4	5
3. Die Anwendung hat mich strukturiert durch die Aufgabe geführt.	1	2	3	4	5
4. Die Aufgabe hat bei mir zu Frustration geführt.	1	2	3	4	5

E.2.2 Post Survey Questionnaire

Nachbefragung

Proband:	
Zeit_01_ Anwendung:	
Zeit_02_ Anwendung:	
Zeit_03_ Anwendung:	

1. Was hat dich am meisten gestört?

2. Was fandest du besonders gut?

3. Sind dir die speziellen Features aufgefallen (z.B. Amazon bietet Zusatzinformationen an)

F Heuristics for Second Screen Applications

All material presented in the following was created in collaboration with Daniel Schmaderer, as part of his bachelor's thesis, supervised by the author (cf. Chapter 9).

F.1 Study Experts

F.1.1 Demographic Questionnaire

Fragebogen Vorher – Experten

ID:

Demographische Daten:

1. Alter: ___ Jahre
2. Geschlecht: [ ] weiblich [ ] männlich
3. Beruf: _____
   a. Wenn Student: Studienfach/ -fächer _____
   b. Wenn Student: __ Semester

Erfahrung:

4. Wie lange entwickeln Sie mobile Anwendungen?
5. Wie lange nutzen/ entwickeln Sie Second-Screen-Anwendungen?
6. Wie lange bewerten Sie Usability bei Projekten?

F.1.2 Questionnaire Evaluation Heuristics

Fragebogen Nachher – Experten

S1: The checklist measures the variable effectiveness.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

S2: The checklist measures the variable efficiency.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

S3: The checklist measures the variable satisfaction.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

S4: The checklist has a good cost-effectiveness.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

F.2 Study Evaluation Users

F.2.1 Demographic Questionnaire

Fragebogen Vorher – Audi Media TV

ID:

Demographische Daten:

1. Alter: ___ Jahre
2. Geschlecht: [ ] weiblich [ ] männlich
3. Beruf: _____
   a. Wenn Student: Studienfächer _____
   b. Wenn Student: __ Semester

Vorwissen:

4. Besitzen Sie einen Smart TV?
   [ ] Ja [ ] Nein
5. Besitzen Sie eine Fire TV – Box?
   [ ] Ja [ ] Nein
6. Besitzen Sie ein Smartphone?
   [ ] Ja [ ] Nein
7. Wie lange benutzen Sie den Fernseher pro Tag? _____
8. Wie lange benutzen Sie Ihr Smartphone pro Tag? _____
9. Haben Sie schon eine „Second Screen“ (Verbindung zwischen Smartphone und dem Fernseher) – App benutzt?
   [ ] Ja [ ] Nein
   a. Wenn Ja, welche _____
10. Wie oft benutzen sie Second Screen Apps pro Woche?
    [ ] täglich [ ] 2 bis 3 mal [ ] 1 mal [ ] nie [ ] _____
11. Nutzen Sie ihr Handy während Sie Fernsehen?
    [ ] Ja [ ] Nein
    a. Wenn Ja: Was genau schauen Sie sich am Handy an?
       [ ] Soziale Netzwerke [ ] Spiele [ ] Informationen zum aktuellen Fernsehprogramm [ ] _____

F.2.2 Tasks User Study

Tasks für Nutzerstudie:

ID:

1. Verbinden Sie das Smartphone mit dem TV.

2. Suchen Sie das Video „Eine Zukunft ohne Lenkrad“ unter der Kategorie "Pilotiertes Fahren" über das Menü und fügen es zu Favoriten hinzu.

3. Suchen Sie über die Suchleiste das Video „Mission to the Moon - Die Reise“ und fügen des zur Playlist hinzu.

4. Starten Sie das Video „Mission to the Moon – Die Reise“. Pausieren Sie das Video nach kurzer Zeit und navigieren Sie zur Übersichtsseite „Aktuell“.

5. Spulen Sie das Video vor und sehen Sie sich die letzten 10 Sekunden an.

F.2.2 Questionnaire Evaluation Test Application

Fragebogen zur Applikation – Audi Media TV

1. Würden Sie die Applikation benutzen und wieso?

2. Was würden Sie ändern?

3. Was finden Sie gut an der Applikation?

Content of the Digital Appendix

Contents created in cooperation with other persons have been marked accordingly in the digital appendix.

/1_Dissertation	Written dissertation as PDF and DOCX files
/2_Part I	Raw data of the SRL and market analysis and all cited sources
/3_Part II	The 2ndS SDK and created prototypes
/3_ Part II /2ndS SDK	Data regarding the requirements, evaluation, and the actual 2ndS SDK itself.
/3_ Part II /Prototypes	Prototypes files with associated study data
/4_ Part III	Studies regarding the optimization of second screen interaction
/4_ Part III/Application Components	Cultural probe and validation study of the mixed-methods approach
/4_ Part III/Attention Direction	Data of both studies on the direction of attention in second screen applications
/4_ Part III/Guidelines	Analysis of existing design recommendations and data of validation study
/4_ Part III/Heuristics	Materials for the derivation of heuristics for second screen applications and data of validation study
/5_Figures	Figures created for the dissertation