UNIVERSITY OF THE WEST of SCOTLAND

Spontaneous Utilisation: A Classic Grounded Theory of Utilising Ambient Displays in Authentic, Co-Located, Matured, and Large-Scale Agile Software Development Environments

by

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To Christoph

Declaration

The research presented in this thesis was carried out by the undersigned. No part of the research has been submitted in support of an application for another degree or qualification at this or another university.

Signature: 

Date: 21st April 2020

Abstract

This research contributes towards an interdisciplinary problem area concerning the long-term deployment of socially embedded technology in authentic environments. In-situ evaluations have the potential to explore how technology is utilised in the real world and are reported to most notably affect both science and society. Nowadays, in-situ research has gained particular momentum in the domains of computer-supported cooperative work and ubiquitous computing. However, such endeavours embody demanding enterprises that require new ways of conceptualisation. The present research elaborates on this issue by drawing attention to the case of ambient displays. Here, a general lack of long-term field deployment studies is observable. This led to the circumstance that in-the-wild research of ambient displays—in all their many forms—lack methodological development.

The two main contributions of this work seek to advance this situation on both a findings and methodological level. To this end, this research scrutinised a custom ambient display solution that leveraged large and interactive displays. For more than five years, the solution was deployed in the agile software development department of a German company. Classic grounded theory was used as a means to methodologically guide the evaluation. The resulting substantive theory—exemplified by its core category of *Spontaneous utilisation*—conceptually and theoretically reflects the field deployment.

The novelty value of the proposed revelatory theory is underlined by missing general theories in the domain of large display research. Essentially, this work portrays a first stepping stone towards the goal of providing methodological guidance for longitudinal evaluations of ambient displays in the wild.

Writing and Citation Conventions

The *APA Style*[1] guide was consulted in creating the present document to maintain a coherent look. Selected conventions are listed below:

- Firstly, numbers greater than or equal to 10 are represented numerically. Accordingly, the numbers one through nine are expressed in words. Exceptions to this rule are:
  - When numbers occasionally begin a sentence, words are consistently used to express them.
  - Numbers are represented numerically when they are grouped in comparisons (e.g. 5 out of 15) or ranges of values (e.g. 5 to 15) with numbers greater than or equal to 10, used in conjunction with mathematical functions (e.g. 5%), and represent exact and not approximate units of measures (e.g. seconds and metres).
- Secondly, decimal numbers are presented including two decimal places and a decimal point (e.g. 1.23). Exceptions are made to this rule when more decimal places are required. Leading zeros are maintained in decimal figures except in cases where a value can never exceed 1.0 such as the p-value. On the contrary, percentage figures have up to two decimal places.
- Thirdly, numbers greater than or equal to 1,000 use commas to separate each group of three numbers (e.g. 1,234,567).

[1] https://apastyle.apa.org/

- Fourthly, direct quotes stemming from both the literature and material from this research "... are placed between *double* [emphasis as in original] quotation marks." Omissions are indicated by ellipses (...) and comments—or meaning—by brackets, while ellipses are not used at the beginning or the end of a quotation. Exceptions to the rule of not using leading ellipses are only made on introduction pages of the individual chapters.

- Fifthly, *italics* are used sparingly in the text (i.e. not utilised for emphasis purposes), but are leveraged to indicate titles (e.g. book titles) and names of things (e.g. software frameworks, terms, labels, and foreign words). While labels and foreign words are italicised in subsequent appearances; terms, titles, and names are italicised when they first appear. In figures, italics are additionally used as a stylistic means.

- Sixthly and lastly, abbreviations are also used sparingly. Considered standard abbreviations (e.g. "USB" and "API") are not further introduced as familiarity with these terms is assumed.

Furthermore, the *UWS Referencing Guidelines*[2] were consulted to create the referencing system in this work. To this end, the LaTeX *Harvard citation package*[3] was utilised, whereas the style variant *apsr* was chosen. However, some revisions were made to increase the readability (e.g. inserting additional punctuation). Finally, the following thesis is written in the British English language style, including the Oxford comma.

[2] https://www.uws.ac.uk/library/using-the-library/referencing/
[3] https://ctan.org/pkg/harvard?lang=en

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List of Publications

1. Schwarzer, J., von Luck, K., Draheim, S., and Koch, M. (2019). 'Towards Methodological Guidance for Longitudinal Ambient Display in Situ Research'. In *Proceedings of 17th European Conference on Computer-Supported Cooperative Work - Exploratory Papers*. Reports of the European Society for Socially Embedded Technologies (ISSN 2510-2591). doi: 10.18420/ecscw2019_ep07.

2. Koch, M., von Luck, K., Schwarzer, J., and Draheim, S. (2018). 'The Novelty Effect in Large Display Deployments – Experiences and Lessons-Learned for Evaluating Prototypes'. In *Proceedings of 16th European Conference on Computer-Supported Cooperative Work - Exploratory Papers*. Reports of the European Society for Socially Embedded Technologies (ISSN 2510-2591). doi: 10.18420/ecscw2018_3.

3. Schwarzer, J., Wang, Q., Casaseca, P., Allison, I., von Luck, K., Draheim, S., and Grecos, C. (2017). 'Ambient Surfaces: Encouraging Communication Beyond Agile Practices in Co-Located Scrum Teams'. In Abel Usoro and Daune West (eds.), *Smart Systems For Complex Problems – Abstracts (IIMA 2017)*. Paisley, Scotland: University of the West of Scotland. pp. 74–75.

4. Schwarzer, J., Draheim, S., von Luck, K., Wang, Q., Casaseca, P., and Grecos, C. (2016). 'Ambient Surfaces: Interactive Displays in the Informative Workspace of Co-Located Scrum Teams'. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction (NordiCHI '16)*. New York, NY, USA: ACM. pp. 69:1–69:4. doi: 10.1145/2971485.2971493.

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Listings

List of Abbreviations

API	Application programming interface
ASD	Agile software development
CSCW	Computer-supported cooperative work
GT	Grounded theory
HCI	Human–computer interaction
IQR	Interquartile range
IT	Information technology
QR	Quick response
REST	Representational State Transfer
SD	Standard deviation
TRL	Technology Readiness Level
Ubicomp	Ubiquitous computing

Chapter 1

Introduction

> "... to make sense of the world of technologies in practice, our work as researchers is to pull together and tease apart dynamic and multiple entities."
>
> —Bjørn and Boulus-Rødje (2015, p. 342)

1.1 Motivation

In-situ evaluations have gained momentum throughout the domain of human–computer interaction (HCI), but particularly in the disciplines of computer-supported cooperative work (CSCW) and ubiquitous computing (Ubicomp) (Siek et al., 2014). In CSCW, field deployment research finds its roots in seminal ethnographic studies (e.g. Bentley et al., 1992; Hughes, Randall, and Shapiro, 1992) which, in the 1990s, informed

computer scientists to develop innovative technological artefacts (Wulf et al., 2015). Similarly, the field of Ubicomp has a rich body of literature on field deployments which has started growing more recently (Siek et al., 2014). For instance, studies began focusing on developing evaluation frameworks (Scholtz and Consolvo, 2004), raised concerns of already-established concepts such as of interaction (Hazlewood, Stolterman, and Connelly, 2011), and put forth issues surrounding the degree of integration (i.e. pervasiveness) as well as the extent of realistic conditions that underlay evaluations (Favela, Tentori, and Gonzalez, 2010). The field's foundations lay in ideas originally proposed in the early 1990s by Weiser (1991), who envisioned seamlessly integrating interlinked computers in people's everyday lives. In HCI, there is also a long-lasting tradition in coping with limitations of lab-based studies which, for example, Thomas and Kellogg (1989, p. 79) acknowledged as "ecological gaps" three decades ago.

Historically, socially embedded technology challenged and changed practices like hardly any other technological artefact before (Wulf et al., 2015). Investigating technology in situ fundamentally warrants new ways of how research is conceptualised as people and practices are more than just their relationships with technology (Bjørn and Boulus-Rødje, 2015). Here, practices and technology become intertwined and embody continuously changing entities that are redesigned and reorganised (Bjørn and Boulus-Rødje, 2015). Hence, Wulf et al. (2015) propose rethinking design practices and combining inspirational creativity and evaluative methods. Although in-the-wild research is considered expensive, time-consuming, and resource-intensive, it simultaneously sheds light on authentic usage and highlights how technology interacts with the environment in terms of, for instance, social and organisational constraints on use (Siek et al., 2014). Contrary to other types of research (e.g. laboratory experiments), in-situ research enables the investigation of long-term effects and provides researchers with a means to cope with issues that arise from a technology's novelty (Alt et al., 2012).

Generally, longitudinal in-the-wild studies are considered valuable as they allow us to scrutinise how a technology is adapted in the real world (Alt et al., 2012; Preim, Ropinski, and Isenberg, 2018; Siek et al., 2014). The complexities of operational feasibility can only be determined in the field (Nunamaker Jr. et al., 2015), whereas social aspects are becoming a constitutive part of the research (Bjørn and Boulus-Rødje, 2015). Con-

sequently, the ecological validity of the obtained data stemming from in-situ research is assumed high (Alt et al., 2012). Despite its challenging nature (Alt et al., 2012; Siek et al., 2014), in-the-wild research simultaneously affects both science and society most notably (Nunamaker Jr. et al., 2015). Recent contributions from a variety of disciplines such as information systems (e.g. Nunamaker Jr. et al., 2015), HCI (e.g. Börner, Kalz, and Specht, 2013; Matthews, Rattenbury, and Carter, 2007; Messeter and Molenaar, 2012; Siek et al., 2014), information visualisation (e.g. Preim, Ropinski, and Isenberg, 2018), CSCW (e.g. Bjørn and Boulus-Rødje, 2015), and Ubicomp (e.g. Hazlewood, Stolterman, and Connelly, 2011) stress the relevance of such endeavours. Furthermore, quite a few studies specifically emphasise calls for more longitudinal in-the-wild research (e.g. Börner, Kalz, and Specht, 2013; Hazlewood, Stolterman, and Connelly, 2011; Preim, Ropinski, and Isenberg, 2018).

1.2 Problem Statement

This research draws attention to the field of ambient displays—a subarea of the Ubicomp discipline (Mankoff et al., 2003). Although one reportedly must enter the field to reliably know a result (Siek et al., 2014), ambient display field deployment research fails to scrutinise examples in practice over a longer period of time (Börner, Kalz, and Specht, 2013). However, they need to be understood in situ, not in lab-based environments (Skog, Ljungblad, and Holmquist, 2003). Evidently, ambient display in-situ research fundamentally misses methodological advances that guide researchers in such endeavours (Hazlewood, Stolterman, and Connelly, 2011). There is a lack of sufficient standard methods for evaluating ambient displays in the wild (Shelton and Nesbitt, 2017) and the difficulties associated with these evaluations increase in authentic environments (Favela, Tentori, and Gonzalez, 2010).

In response, the present thesis aims to envision methodological guidance for longitudinal research endeavours of ambient displays in the wild. To this end, it sheds light on an investigation of a custom ambient display solution (see Section 3.4) in an

authentic, co-located, and matured agile software development (ASD)[1] environment (see Section 3.3). Simultaneously, this research seeks to contribute the novel long-term findings of this investigation that are embodied in a substantive theory generated by applying classic grounded theory (GT) methodology (see Section 3.2.2).

1.3 Assumptions

There are certain assumptions that underlie the present thesis. Firstly, it is assumed that the context in which the research is conducted is an exemplary representative sample for similar environments in ambient display field deployment research. Likewise, the custom prototype utilised here is understood as an exemplary ambient display solution that leverages large and interactive displays. Secondly, it is assumed that the research's participants were honest and truthful in their feedback. It is assumed that the research's attendees had a genuine interest in participating in the study and were not influenced by other incentives (e.g. job promotion). Lastly, it is assumed that the hardware sensors utilised gave accurate data.

1.4 Significance of the Study

Arguably, the significance of this study largely arises from the very nature of ambient displays as their user experience radically stands in contrast to traditional task-orientated situations (Hazlewood, Stolterman, and Connelly, 2011). This issue is embodied in the fact that there is still a technology-driven research focus that largely ignores how actual operation relates to people's everyday lives (Matthews, Rattenbury, and Carter, 2007). Social aspects fundamentally have received little attention and it is warranted in broadening the scope of investigation (Messeter and Molenaar, 2012). This may explain the reason why it is still one of the most striking issues to find useful adoption scenarios for which Koch, Ott, and Richter (2014, p. 5) call "natural user interfaces" in practice. Evidently, examinations are needed that address the subject

[1] Following the instructions of official guidelines (Schwaber and Sutherland, 2017), agile-related terms are consistently written with leading capital letters in this document (e.g. Scrum Master and Sprint).

of scrutinising ambient displays in the wild more holistically. The issue is exemplified by literature that argues against pruning methodology and welcomes research "whose coherence in presentation is mainly shaped by the practices undergoing investigation" (Wulf et al., 2015, p. 145).

The present thesis affects existing knowledge in various ways and its relevance is underlined by multiple publications. Chapter 5 returns to this topic and elaborates on contributions to existing knowledge more thoroughly.

1.5 Delimitations

This research also builds on certain delimitations. Firstly, a German ASD company was chosen for this study (see Section 3.3). This sample selection originates from an already-established collaboration prior to the study. This readily availability was the primary inclusion criteria. Secondly, it was decided to concentrate on both the issue of methodological advances and of the resulting lack of long-term findings in the domain of ambient display research as both issues felt most far-reaching (see Section 2.5). Thirdly, as a foundation for the overall knowledge-seeking process, the present dissertation proposes classic GT methodology (see Section 3.2.2) as a suitable candidate to conduct longitudinal ambient display field deployment research. Classic GT was chosen as apparently no existing methodology accounts for the complexity of such enterprises and provides sufficient guidance. As opposed to other methodologies utilised in this domain such as surveys (Börner, Kalz, and Specht, 2013), it was initially decided to approach this research *tabula rasa*. Fourthly, the research initially focused strongly on sensor data stemming from hardware sensors in the monitors' frames primarily due to anticipated time-consuming work tasks relating to observations. Lastly, the choice to select a mixed-methods approach (see Section 3.2.3) originated from the fact that a variety of different data collection methods (e.g. observations and sensor data) is typically utilised in large display research (Alt et al., 2012). Generally, researchers are encouraged to leverage multiple methods in field deployment research (Siek et al., 2014).

1.6 Definition of Key Terms

The following introduces terms that felt particularly relevant to better comprehend the research and the reader is encouraged to keep them in mind.

Ambient Display An *ambient display* is an interaction approach that uses ambient media in the periphery of users (Börner, Kalz, and Specht, 2013). It can be understood as a solution that: firstly, displays important information; secondly, can move from the periphery to a person's attention and vice versa; thirdly, is a tangible representation in the physical environment; fourthly, indicates subtle changes of information (i.e. updates); and fifthly, is environmentally appropriate as well as aesthetically pleasing (Pousman and Stasko, 2006). The custom ambient display solution utilised in this work—henceforth referred to as *Ambient Surfaces* (see Section 3.4)—addresses a special sub-class of ambient displays that is concerned with "supporting informal, nonurgent communication, collaboration, and awareness" (Huang et al., 2006, p. 37). It represents a form of ambient displays that leverages large and interactive screens to display information. Furthermore, the research concerns solutions in a semi-public workplace setting, which demonstrates an intersection between the personal and the public space (Börner, Kalz, and Specht, 2013).

Large-Scale, Co-Located, and Matured Agile Software Development The chosen ASD context (see Section 3.3) is characterisable by dimensions surrounding its size (i.e. *large-scale*), team location (i.e. *co-located*), and experience with the practice of ASD (i.e. *matured*). A large-scale ASD environment typically consists of two to nine agile teams (Dingsøyr, Fægri, and Itkonen, 2014), while the team number in the participating company varied between four and eight agile teams throughout the research. Co-location refers to the fact that teams are not distributed (e.g. across different countries) but work together in close proximity (Strode, 2016). A company is considered matured in using ASD when agile methods have been in operation for at least one year (Dybå and Dingsøyr, 2008; Santos, Goldman, and de Souza, 2015). The participating company initiated the transformation to ASD roughly a year prior to the present research in 2013.

Longitudinal Research The term *longitudinal*—interchangeably referred to as *long-term*—means that the present thesis incorporates data stemming from a multiple-year enterprise (i.e. 2014 to 2019). It is geared towards a recent literature review on ambient display research (Börner, Kalz, and Specht, 2013), in which longitudinal field deployments are described as endeavours that potentially last several months.

In-Situ, Field Deployment, and In-the-Wild Research *In-situ*—in the literature alternatively referred to as *field deployment* or *in-the-wild*—research enterprises are characterised by the following attributes (Siek et al., 2014):

1. They seek to investigate how novel technology and factors such as populations, activities, and tasks impact each other.

2. They are conducted in the context of use.

This document leverages these terms synonymously to introduce variation in the text. Leaning towards the *Technology Readiness Level* (TRL) scale of the European Union (Héder, 2017), these terms are targeted at solutions starting on TRL 5 (i.e. technology is evaluated in the relevant environment). The Ambient Surfaces prototype (see Section 3.4) utilised here is understood as a solution on TRL 7 as it was demonstrated in an operational environment.

Substantive and Formal Theory Glaser and Strauss (1967) describe a *substantive theory* as a theory that is developed for an empirical (i.e. substantive) area of inquiry. *Formal theory*, on the contrary, means that theory is formed from a conceptual (i.e. formal) area. It is encouraged to concentrate on one of both levels (as in this research) or on a specific combination as their generating process differs. Substantive theory assists in creating new or revising existing formal theories based on data. Each type of theory indicates a distinguishable level of generality. While substantive generality is yielded by transferring a substantive theory to another substantive area, formal generality is achieved by considering many substantive areas (Glaser, 1998).

Fundamentally, theory in classic GT comes in the form of a concept-indicator model (Glaser, 1978), meaning that empirical findings (i.e. the *indicators*) are reflected con-

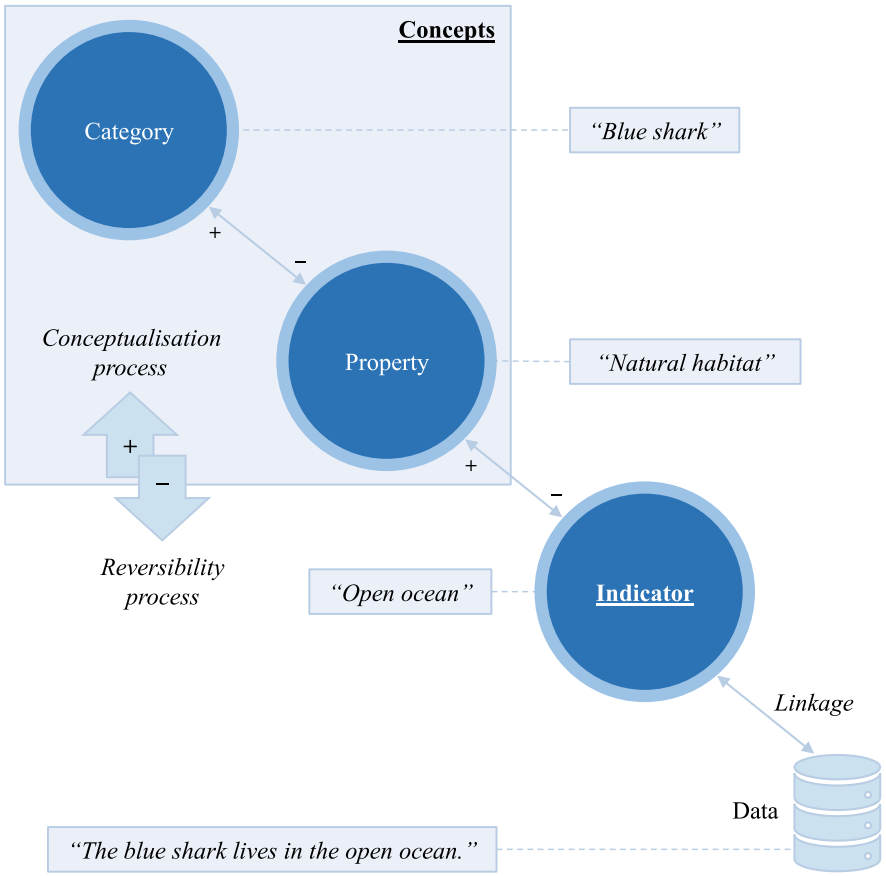

Figure 1.1: An illustration of classic GT's concept-indicator model based on elaborations from Glaser (1978) and enriched by a brief example.

ceptually (see Figure 1.1). *Concepts* are what is referred to as *categories* and their subordinated *properties* in GT methodology. While the abstraction level increases during the conceptualisation process with each increment (i.e. by creating more abstract concepts), concepts can always be linked back to the data through the indicators which empirically informed their creation (i.e. the reversibility process).

Section 3.2.5 returns to the data processing procedure of classic GT and introduces the different terms more thoroughly, while this section intends to convey a first, rough idea on the methodology's terminology.

Spontaneous utilisation This custom-labelled term resulted from applying classic GT in this work and embodies the core category of the proposed theory. While the word *spontaneous* is meant to exemplify how study participants resolved describing their usage of the Ambient Surfaces, *utilisation* refers to the varying ways in which people engaged with the systems. Three types of utilisation were identified (see Section 4.3.3):

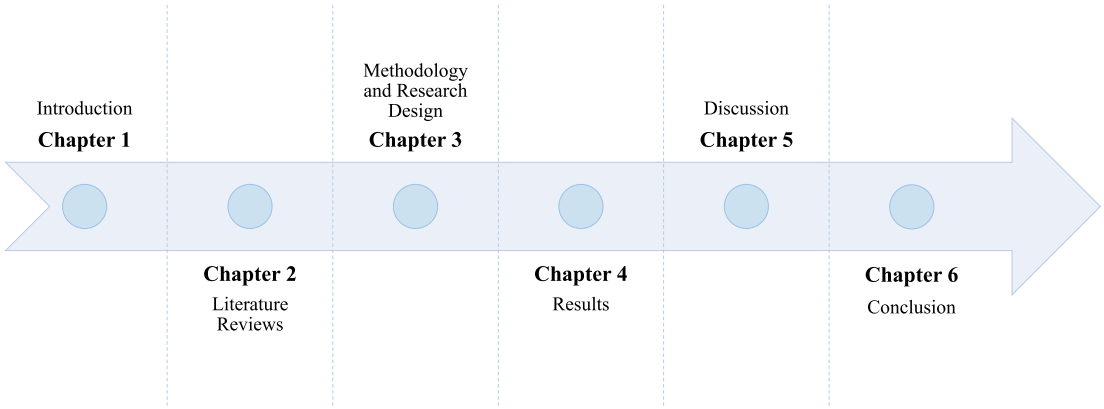

Figure 1.2: The overall organisation of this thesis including its six chapters.

firstly, people were interacting with screens' surfaces (labelled *Type 1*); secondly, people were passively paying attention to information, for example, while standing in front of the systems (labelled *Type 2*); and thirdly, people were just briefly looking at the screens while passing by (labelled *Type 3*).

1.7 Organisation of the Remainder

This thesis is divided into six chapters (see Figure 1.2). Following the introduction in Chapter 1, Chapter 2 continues to collate the relevant literature work activities conducted throughout the research. Subsequently, Chapter 3 addresses methodological aspects and illustrates the research design. Chapter 4 then presents the results obtained by following classic GT methodology, which led to the emergence of the proposed theory, including its core category of *Spontaneous utilisation*. Thereafter, Chapter 5 critically reflects on this research, presents contributions to existing knowledge, and discusses limitations. Finally, Chapter 6 illustrates conclusions, research implications, and directions for future research.

Chapter 2

Literature Review

> "... ambient displays, in all their many forms, constitute a new form of user experience that is radically different from the traditional focused task-oriented user situation. As a consequence we argue for methodological development when it comes to evaluation of these technologies."
>
> —Hazlewood, Stolterman, and Connelly (2011, p. 877)

2.1 Introduction

The following summarises the major stepping stones made during the literature work in this classic GT study. A chronological depiction of crucial activities is visually illustrated in Figure 2.1. Fundamentally, this thesis embodies a continuation of previous work (Barnkow, Schwarzer, and von Luck, 2012, 2013; Schwarzer et al., 2013; Schwarzer, Barnkow, and von Luck, 2013; Schwarzer, Draheim, and von Luck, 2015; Schwarzer

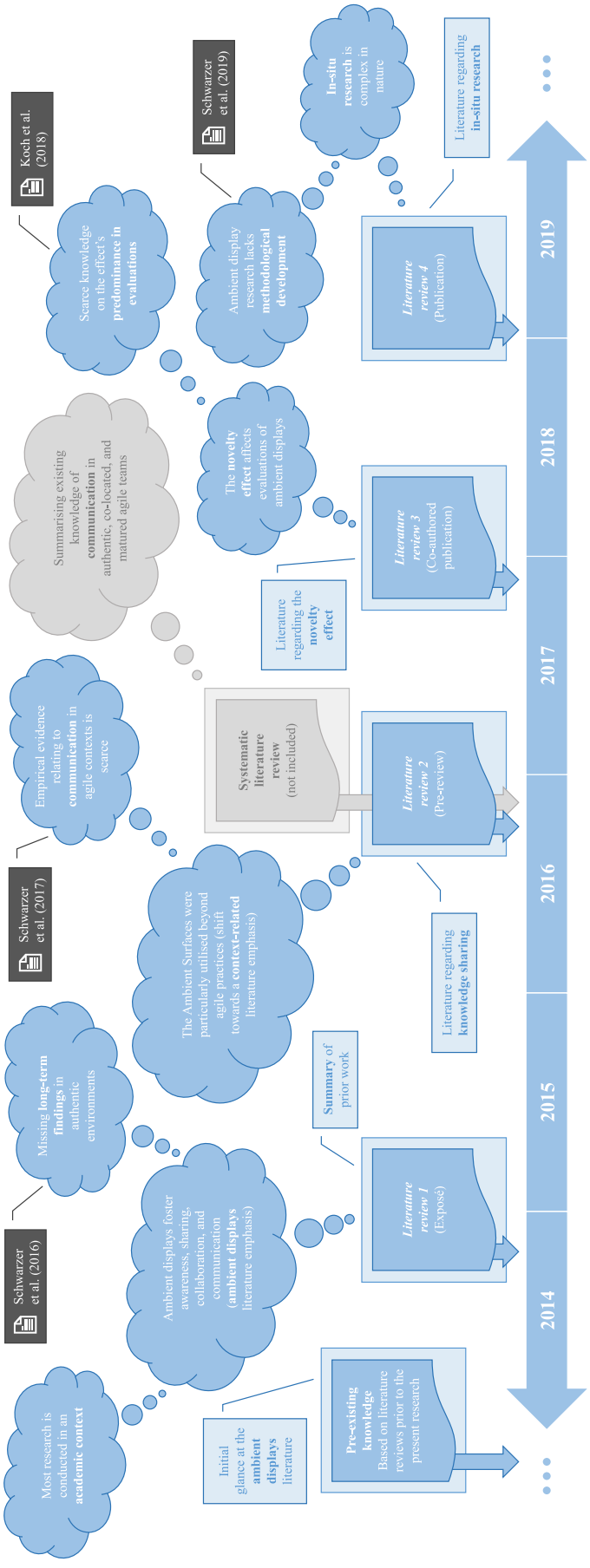

Figure 2.1: Essential literature work packages conducted throughout the study. A few initial issues relating to the various review stages are highlighted in the corresponding cloud shapes. While publications are indicated by dark grey rectangles, excluded work packages are highlighted in a light grey colour.

and von Luck, 2012), while its aim emerged through and was shaped by changing literature emphases. This chapter elaborates the different shifts in the literature work and indicates the limitations of existing knowledge, which finally led to the formulation of the primary research aim.

The remainder is organised as follows: initially, Section 2.2 explains rudimental aspects surrounding literature work in classic GT and introduces the chosen stance on this issue in the present research. Subsequently, the literature reviews conducted are illustrated in Section 2.3. While Section 2.4 then summarises the identified lack of existing knowledge in an overview, Section 2.5 sheds light on the primary research aim. Finally, Section 2.6 recaps and concludes Chapter 2.

2.2 Literature Work in Classic Grounded Theory

This section addresses the issue of conducting literature work in classic GT methodology (see Section 2.2.1) and introduces the chosen approach in this thesis (see Section 2.2.2).

2.2.1 Conflicting Positions on the Timing

Literature work in classic GT stands in contrast to traditional approaches (Glaser, 1998). It recommends not commencing any activities in substantive and related areas until the near completion of a theory. The point is that the relevant literature is unknown until core parts of a theory arise. Such literature may even stem from far afield and often comes as a surprise, meaning that articles from other fields may become part of a theory. The researcher is initially not aware of both what theory is to be discovered and of the relevant literature that describes the fundamental elements of an emergent theory. Suspending knowledge in a particular area and reading in other substantive areas assures sensitivity. It is recommended to avoid any pre-research reviews, as preconceived ideas potentially affect the emergence of a theory. However, there are occasions that may necessitate preliminary literature work (e.g. a PhD thesis). Here, Glaser (1998) encourages abiding by university requirements and satisfying committees.

Reviewing the literature in GT poses a unique challenge for the researcher (Hunter, 2014). In the broader GT community, the postponing characteristics in classic GT

are criticised. An ongoing scholarly contentious debate reflects this issue, while two contemporary approaches are prevalent (Giles, King, and de Lacey, 2013). Firstly, as practised in classic GT, postpone literature work until after both data collection and analysis have started and, in some cases, also until codes and categories emerge. This firm stance is considered *naïve* as reading the literature is delayed in favour of openness to data (Muller and Kogan, 2012). According to Urquhart and Fernández (2013), this circumstance resulted in the misconception that a GT researcher must be a *tabula rasa*. Secondly, conduct a preliminary literature review prior to the study and subsequently expand this review or commence a secondary review during the process of collecting and analysing data.

The conflicting argument stems from two distinct beliefs in how preconceived ideas and bias affect the overall theory-generating process from its inception (Giles, King, and de Lacey, 2013). While classic GT consistently promotes the avoidance of preliminary literature work (Glaser, 1978, 1998; Glaser and Strauss, 1967), others are at odds with this view. It is argued that familiarity with related literature can enhance sensitivity towards nuances in the data (Corbin and Strauss, 2015). Generally, Charmaz (2014) and Corbin and Strauss (2015) make the argument that researchers typically possess some degree of knowledge in their field of interest prior to the research. Such knowledge is essential in certain cases as examining committees expect it (Charmaz, 2014). Furthermore, disciplines such as CSCW and HCI demand research to provide novel contributions, which according to Muller and Kogan (2012) implies extensively studying the literature in advance.

Overall, increasing evidence supports preliminary literature work in GT research (Giles, King, and de Lacey, 2013). Nonetheless, Urquhart and Fernández (2013) conclude that all key texts on GT encourage engagement with the extant literature at some point and provide a means to deal with bias stemming from pre-existing knowledge. Classic GT's general stance is to consider literature as just another data source to be incorporated in the overall analysis process (Glaser, 1998)—whether at the beginning of a study (i.e. if a preliminary review is required) or later during the sorting and writing stage of the emergent theory.

2.2.2 Thesis Approach

Seemingly, some consensus on literature work in GT research exists as Glaser (1998) acknowledges cases where circumstances may necessitate relaxing the rule of delaying such tasks (e.g. PhD theses). It is the author's understanding that the boundaries between these conflicting positions on literature work are becoming somewhat dissolved in such situations and the researcher must find a practical solution to cope with this issue. As a useful direction on this avenue, Hunter (2014) suggests an approach introduced by Urquhart and Fernández (2013), who propose a *non-committal phase* and an *integrative phase* during literature work. While the former concerns scanning the literature to pinpoint the research problem and becoming familiar with the methodology, the latter addresses the comparison of extant theories with the emerging theory. The non-committal phase is not intended to define research questions, but to locate the scope of investigation. This phase continues as a research project progresses. During the integrative phase, further literature reviews are suggested to converge and diverge the literature with the emerging theory during analyses (i.e. the literature is treated as another data source), and to integrate the core pattern with the wider extant theory.

The reason to choose this organisation was twofold: firstly, it provides practical guidance to structure literature work in classic GT, and secondly, it has already shown applicability in other doctoral dissertations (e.g. Hunter, 2014). However, this research did not transcend into the integrative phase, primarily due to the fact that the research was running out of time. Although great efforts were made in this regard (see Figure 2.1), it was decided to discontinue this phase at some point and to exclude it from this thesis. Impacting factors were GT's demanding learning curve (Glaser, 1998) and the challenge of bringing methodology to the field of ambient display in-situ research as introductorily illustrated. This decision was also affected by the circumstance that a substantive theory has contributing value on its own and does not necessarily need to be integrated with the extant literature (Glaser, 1998). Progressively, it was understood that substantial contributions do not solely arise from proposing a theory that is rigorously integrated with the extant literature, but rather from its overall methodological integration and the results obtained by adhering to this rationale.

Fundamentally, the non-committal phase served as a means of shaping this research's problem area and directing the study into niches that embodied fruitful avenues on which to concentrate the research. While this largely assured not weaving preconception into the theory-generating process, it simultaneously assisted in yielding gaps of existing knowledge. Overall, the literature work was a continuous process that constantly shaped this research. The different reviews were not necessarily scheduled in advance but were a result of, for instance, collaborations with other research groups. Furthermore, the author's pre-existing knowledge affected the research primarily in its early stages to inform its commencement (i.e. the intention to conduct a longitudinal study). Exemplified by the two research gaps to which this research seeks to contribute towards (see Section 2.5), his pre-existing knowledge has rather not biased the process of generating theory.

In summary, the chosen stance on literature work embodies a compromise between being able to indicate novelty and to stay truthful in terms of generating theory. The research embarks upon finding a feasible approach to recommendations in classic GT (Glaser, 1998) to, one the one hand, satisfy committee requirements and, on the other hand, to solely consider literature during a research project's latter stages whilst sorting and writing up a theory.

2.3 Non-Committal Phase: Literature Reviews

This section continues with literature work conducted during the non-committal phase. It highlights, how the focal point of the research evolved over time. Therefore, it starts off with an illustration of pre-existing knowledge which was brought along (see Section 2.3.1). Subsequently, it continues with four literature reviews, respectively referring to the research's exposé (labelled *Literature review 1*, see Section 2.3.2), a pre-review that preceded the systematic literature review not included (labelled *Literature review 2*, see Section 2.3.3), a review relating to a 2018 co-authored publication (labelled *Literature review 3*, see Section 2.3.4), and finally, a literature review in the context of a 2019 publication (labelled *Literature review 4*, see Section 2.3.5).

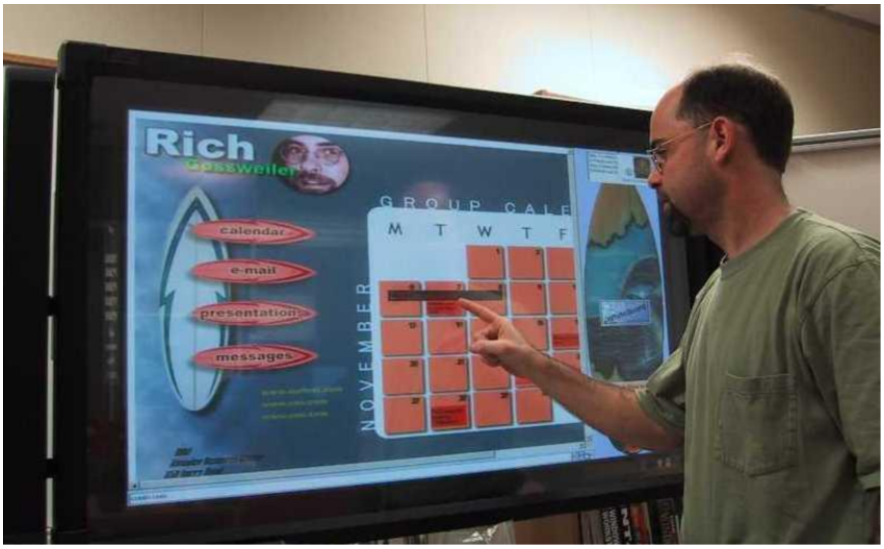

Figure 2.2: The BlueBoard system deployed in a research facility (Russell and Gossweiler, 2001).

2.3.1 Pre-Existing Knowledge

Pre-existing knowledge was largely shaped by the circumstance that literature work between 2010 and 2013 was somewhat less focused and was primarily targeted at becoming sensitive towards the general problem area of ambient display research. The reviewed literature included a variety of different custom prototypes such as the *DynaWall* (Geißler, 1998), *CommunityWall* (Snowdon and Grasso, 2002), *AwareMedia* (Bardram, Hansen, and Soegaard, 2006), *Notification Collage* (Greenberg and Rounding, 2001), *PlasmaPlace* (Churchill et al., 2004), *Stanford Interactive Room* (Borchers et al., 2002), *Blueboard* (Russell and Gossweiler, 2001), and *Community Mirrors* (Koch, 2005). Figure 2.2 and Figure 2.3 show examples of two investigated solutions from this time.

It was also found that there is a multitude of terms—besides ambient displays (Röcker et al., 2004)—that are synonymously used to refer to these devices. The terms utilised are: *public displays* (Churchill et al., 2003), *public interfaces* (Churchill et al., 2004), *semi-public displays* (Huang and Mynatt, 2002), *large screen, digital, interactive, bulletin boards* (Churchill et al., 2003), *large-screen, interactive interfaces* (Churchill et al., 2004), *large interactive displays* as well as *large public displays* (Bardram, Hansen, and Soegaard, 2006), *public computer displays* and *semi-public computer displays* (McCarthy, Congleton, and Harper, 2008), *large display screens* (Satyanarayan et al., 2013), *large displays* (Huang, Russell, and Sue, 2004; Russell and Gossweiler, 2001),

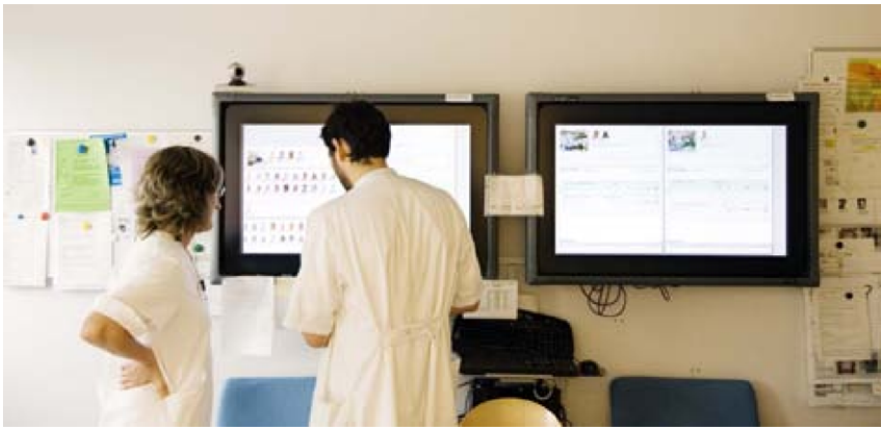

Figure 2.3: The AwareMedia solution deployed in an authentic hospital environment (Bardram, Hansen, and Soegaard, 2006).

real-time collaborative surfaces (Greenberg and Rounding, 2001), *peripheral displays* (Huang et al., 2002; Matthews, Rattenbury, and Carter, 2007; Pousman and Stasko, 2006), *large interactive screens* (Snowdon and Grasso, 2002), *large-scale information displays* (Huang and Mynatt, 2002), and *distributed, large, touch-enabled, plasma displays* (Trimble, Wales, and Gossweiler, 2003). In addition to these varying terms, authors typically label their custom solutions with individual names as previously indicated.

Own literature reviews, publications, and field deployments incrementally began to cover more specific topics of using ambient devices in terms of team collaboration (Barnkow, Schwarzer, and von Luck, 2013), information awareness (Barnkow, Schwarzer, and von Luck, 2012), and work appreciation (Schwarzer et al., 2013; Schwarzer, Barnkow, and von Luck, 2013). In summary, the literature work revealed that research fails to present examples that become an integral part in daily working environments of industrial settings (Koch and Ott, 2011). Furthermore, research indicated that the process of customising and prototyping these physical devices is arduous (Borchers et al., 2002). Finally, Russell and Gossweiler (2001) corroborated design issues as one has to consider a variety of user populations and locations in creating such media.

2.3.2 *Literature review 1*: Exposé

In the third quarter of 2014, past activities and the limitations of existing knowledge of large display research were collated within an exposé, primarily by the means of back-

ward reference searching. The reviewed body of literature built on 17 different studies including the aforementioned work of Geißler (1998), Snowdon and Grasso (2002), Bardram, Hansen, and Soegaard (2006), Greenberg and Rounding (2001), Churchill et al. (2004), Borchers et al. (2002), Russell and Gossweiler (2001) as well as the studies from Churchill et al. (2003), Fass, Forlizzi, and Pausch (2002), Huang and Mynatt (2002), Huang et al. (2002), Huang, Russell, and Sue (2004), Koch and Möslein (2006), Koch et al. (2014), Ott, Richter, and Koch (2010), Satyanarayan et al. (2013), and Trimble, Wales, and Gossweiler (2003). Furthermore, the review contained three additional studies which discussed productivity benefits (Czerwinski et al., 2003), taxonomies (Pousman and Stasko, 2006) as well as success and design flaws (Huang et al., 2006).

It was found that 16 out of the 17 studies had been conducted in an academic context and only one study presented findings from an authentic environment (see Figure 2.3). This review underlined earlier findings with respect to the adoption of large displays in the industry. Additionally, a notable amount of existing research (i.e. 13 studies)—and in some cases entirely (e.g. Churchill et al., 2004; Huang et al., 2002)—investigated aspects surrounding the topic of information awareness. There were, however, examples that were intended to encourage communication (e.g. Churchill et al., 2003), collaboration (e.g. Greenberg and Rounding, 2001), and information sharing (e.g. Russell and Gossweiler, 2001). The review complemented earlier results to the following extent:

- Huang and Mynatt (2002) note that deployments targeting larger groups often face challenges regarding privacy concerns, content relevance, and the *modus operandi* (e.g. relying strongly on user input versus automated content). Their findings generally suggest a lack of experience with deployments in shared environments aimed at supporting pairs of individuals, smaller groups (i.e. circa 10 people), and larger groups (i.e. 20 to $\geq$100 people).

- While Czerwinski et al. (2003) note that there is an increasing body of literature regarding large display research, empirical knowledge about their advantages in conducting information work is still scarce. The same holds true for more complex working conditions such as the ones that include multiple projects simultaneously.

Figure 2.4: The C3C system in the spatial environment of staff members in a research facility (McCarthy, Congleton, and Harper, 2008).

- Huang, Russell, and Sue (2004) posit that large display solutions share similarities with their desktop-based counterparts. However, their public and shared nature amplifies the challenges relating to their adoption and success. Primarily, these challenges stem from their different form factors, their broader target audience and location as well as their lack of ownership. The aforementioned seemed to underline the challenges mentioned earlier in terms of designing, customising, and prototyping large display solutions. It is reported that research has still yet to "yield a killer app, a common look and feel for applications, or a set of broadly applicable design principles" (Huang et al., 2006, p. 37). As further pointed out by Huang et al. (2006), large display deployments can also fall into disuse due to inherent hurdles and the fact that these can barely be solved by design.

- McCarthy, Congleton, and Harper (2008) invite research relating to organisational ranks, team membership, and locations. Generally, they encourage research that bridges "the gaps between the online and offline worlds" (McCarthy, Congleton, and Harper, 2008, p. 106). They propose sharing online content via large displays as a means of increasing the sense of community in a broadening range of physical environments such as in the case of their *C3C* system (see Figure 2.4).

In summary, the problem area has now started to develop to an extent that it could be formulated. The exposé proposed the investigation of a custom ambient display solution in an authentic environment as the intended main contribution to existing knowledge. This aim was slightly rephrased for a German publication (Schwarzer, Draheim, and von Luck, 2015) at the largest German HCI conference[1] as it was argued that there were seemingly no longitudinal studies that scrutinise ambient displays in ASD contexts. This argument was exemplified by the fact that it is still one of the most challenging concerns to find meaningful adoption scenarios of natural user interfaces in organisations for day-to-day usage purposes (Koch, Ott, and Richter, 2014). In essence, compared to earlier stages, the emphasis now started to become more focused on reducing the complexity of the overall problem area.

2.3.3 *Literature review 2*: Pre-Review

Starting in late 2015, an English publication was targeted. Following the same argument of the preceding German HCI conference publication, a paper (Schwarzer et al., 2016) was submitted to the 2016 NordiCHI conference[2]. The paper had been accepted with an overall acceptance rate of 18% for conference short papers. In fact, the rare value of the presented long-term findings was highlighted by the meta review. During this time, however, more papers relating to ASD were scanned such as in the context of awareness systems (Downs, Hosking, and Plimmer, 2010; Downs, Plimmer, and Hosking, 2012) and information visualisation techniques (Paredes, Anslow, and Maurer, 2014). These publications put forth:

- There is little evidence on "what constitutes relevant status information and the appropriate modalities for communicating this information" (Downs, Hosking, and Plimmer, 2010, p. 82).
- Paredes, Anslow, and Maurer (2014) stress that it is still not clear how information visualisation tools are better than the stock repertoire of what software developers

[1] http://muc2015.mensch-und-computer.de/
[2] http://www.nordichi2016.org/

are currently using. By referring to the work of Koschke (2003), they conclude that this might be the reason why there are such few adoptions in the industry.

- Long-term research is suggested in the context of ambient devices to overcome phenomena such as the *Hawthorne effect* (Downs, Plimmer, and Hosking, 2012). The Hawthorne effect was coined by Henry A. Landsberger and originates in research conducted in the Hawthorne Works factory in the 1950s (Landsberger, 1958). The effect principally concerns the circumstance that observed members of an experiment tend to outperform their control group, often independently of any intervention. As Downs, Plimmer, and Hosking (2012) further note, an increasing importance for further research of ambient devices also stems from the exploration of their meanings as well as their properties, and the design characteristics which relate to their success. These findings also seemed to underline the aforementioned challenge of designing, customising, and prototyping ambient devices.

This progress led to the decision to conduct a further literature review in August and September 2016. The review set out to discover particular issues in ASD and the literature work now evolved to an extent that did not solely consider topics in the domain of ambient displays, but also concerns stemming from the actual research context. The systematic mapping study from Paredes, Anslow, and Maurer (2014) particularly affected this shift during that time. It elaborated on visualisation techniques (e.g. ambient displays and physical task boards) used in ASD teams to promote knowledge sharing and awareness. The authors revealed that ASD teams utilise visualisation techniques for designing, developing, communicating, and progress tracking purposes. Essentially, the study found that these techniques assist in facilitating knowledge sharing and awareness among team members. In the ASD context, the term *information radiator* (Cockburn, 2002) is also used when referring to the various formats that teams utilise to display and distribute information.

Compared to activities in earlier stages (i.e. mainly backward reference searching), this time, a non-exhaustive list of digital databases (see Appendix A) was leveraged to investigate existing literature. The objective was to gain an initial overview of existing research gaps in this academic context. For this literature review, the project partner's

Table 2.1: Included studies in *Literature review 2*.

Categories	Studies
Knowledge sharing	Santos, Goldman, and de Souza (2015) (found while searching for latest publications from the first author), Neves et al. (2011), Levy and Hazzan (2009), and Melnik and Maurer (2004).
Communication	Hummel, Rosenkranz, and Holten (2013), Hummel, Rosenkranz, and Holten (2015) (found while searching for latest publications from the first author), Mishra, Mishra, and Ostrovska (2012) (found in Hummel, Rosenkranz, and Holten, 2013), and Pikkarainen et al. (2008) (found in Hummel, Rosenkranz, and Holten, 2013).
ASD in general	Rola, Kuchta, and Kopczyk (2016), Barroca et al. (2015), Diebold and Dahlem (2014), Adolph, Kruchten, and Hall (2012) (found in Hummel, Rosenkranz, and Holten, 2015), Dingsøyr et al. (2012) (found in Hummel, Rosenkranz, and Holten, 2015), and Conboy (2009) (found in Hummel, Rosenkranz, and Holten, 2013).

parameters (i.e. authentic, co-located, and matured ASD environment) also affected the selection and reading procedure. For this reason, literature which did not meet these criteria was mostly ignored. Nonetheless, the review was kept open-minded and explorative in nature. For example, literature fundamentally related to ASD was also included. Table 2.1 illustrates the categorised body of literature which was the basis for this review. If studies were obtained other than through the search procedure, text in parentheses provides more information.

However, at some point it was decided to stop reading and to conclude this review. This was primarily due to the discovery of the work from Hummel, Rosenkranz, and Holten (2013), who conducted a comprehensive systematic mapping study with respect to communication in ASD. The authors argue that existing knowledge of communication is limited. Therefore, an understanding of how the particular case of communication in ASD related to the utilisation of the Ambient Surfaces was strived towards. Due to this development, it was then decided to commence a profound systematic literature review based on guidelines provided by Kitchenham and Charters (2007). This review, however, was not included in this thesis (see Figure 2.1) as, again, the literature work did not transcend into the integrative phase. It was understood at some point during analyses that communication-related issues are just one integral part of the proposed theory (e.g. see Figure 4.21c). Literature reviews for the other parts (e.g. awareness

issues) would have been equally necessary to fully relate the theory proposed here to the extant literature. As time resources became a concern, it was, therefore, decided to discontinue the work on the integrative phase and exclude it entirely from this thesis. Nevertheless, the preliminary findings from the review on communication issues were used in the context of a 2017 publication (Schwarzer et al., 2017).

2.3.4 *Literature review 3*: The Novelty Effect

During 2017, a collaboration with another research group was established. The first step was to work on a joint publication, which ultimately resulted in a 2018 co-authored paper (Koch et al., 2018). The literature review conducted for this publication helped to broaden the understanding of a crucial phenomenon in large display evaluations—the *novelty effect*—also referred to as *novelty factor* (e.g. Alt et al., 2012; Guerrero et al., 2016). In summary, the literature review revealed that no formal and comprehensive definition of this effect exists. Principally, the novelty effect can be understood as a phenomenon that refers to manifested patterns in data on the account of novelty that distract from otherwise occurring authentic latent patterns. It was summarised that knowledge regarding the novelty effect in CSCW and HCI research is in its early stages as novelty embodies a complex and highly dependent concept of intertwined variables (e.g. context and involved people). Furthermore, it was elaborated that, apparently, there is a lack of appropriate tools to determine the novelty effect and consequently cope with it on a methodological level. In an attempt to provide an overview of existing knowledge on this effect, the paper summarised literature from different disciplines:

- Findings from behavioural sciences show that it can take up to several months for a new behaviour to take hold (Prochaska and Diclemente, 1982).
- The novelty effect was also contrasted with the Hawthorne effect (Landsberger, 1958). While the latter is about the effect of observation, the former concerns the effect of an innovation's novelty (i.e. whether an observation is conducted or not).
- Also medical psychology literature—particularly the *novelty/encoding hypothesis* proposed by Tulving and Kroll (1995)—was incorporated. This hypothesis puts

forth that the processing of information into long-term memory is affected by its novelty. Other studies such as Kormi-Nouri, Nilsson, and Ohta (2005) and Poppenk, Köhler, and Moscovitch (2010) tested this hypothesis positively in different settings.

- In educational research, it is stated that students learn better when they are supported by computer-based learning material (Kulik, 1994). However, Krendl and Broihier (1992) revealed that both the preferences for and the perception of learning from computers declined significantly over time.

- Furthermore, technology acceptance research, such as in the case of theoretical frameworks like the *Technology Acceptance Model* (Davis, Bagozzi, and Warshaw, 1989), was considered. This model copes with the challenge of predicting user adoption of new technology.

- Finally, research on curiosity stimuli towards website content was incorporated. Huang (2003) found that novelty can be leveraged as a mechanism to create the initial success of a website.

Several papers originating from HCI and CSCW were included in this review. In a comprehensive overview of large display research, Huang et al. (2006) concluded that many deployments indicated strong initial usage, which was followed by more sporadic usage. Some studies (e.g. Gallacher et al., 2015; Hazlewood, Stolterman, and Connelly, 2011; Hosio et al., 2014; Koppel et al., 2012; Lösch, Alt, and Koch, 2017) explicitly acknowledged the novelty effect in their research design. In contrast, other authors stated that they must evaluate their solutions for a longer period of time in future research due to the prevalence of the novelty effect (e.g. Guerrero et al., 2016). There were also studies which were more specific such as the work from Ojala et al. (2012), who observed that the novelty effect reoccurred during their entire study (e.g. when new features were deployed).

Finally, *display blindness* as a further effect was introduced, which basically refers to ignoring displays due to the expectation of uninteresting content (Müller et al., 2009). This effect deserves a special mention as it reflects on how well a deployment

is utilised beyond the prevalence of the novelty effect (Memarovic, Clinch, and Alt, 2015). Furthermore, it was also learned that deployments can suffer from an effect called *display avoidance*, which concerns the circumstance that people purposely do not pay any attention towards an installation due to information overload (Kukka et al., 2013).

In summary, *Literature review 3* initiated a shift away from solely considering the problem area on a findings level. Methodological issues (e.g. how to cope with the novelty effect) started to be woven into the overall consideration and were understood as a fundamental challenge in ambient display in-situ research. This led to the decision to elaborate on this topic further in a subsequent publication (Schwarzer et al., 2019).

2.3.5 *Literature review 4*: In-Situ Research

The last literature review conducted throughout the non-committal phase was carried out in a 2019 publication (Schwarzer et al., 2019). It primarily assisted in advancing the problem area with respect to methodological issues concerning in-the-wild research and ambient display field deployment research in particular. The relevance of in-situ research is embodied in a variety of papers stemming from disciplines such as CSCW (e.g. Bjørn and Boulus-Rødje, 2015), HCI (e.g. Börner, Kalz, and Specht, 2013; Matthews, Rattenbury, and Carter, 2007; Messeter and Molenaar, 2012; Siek et al., 2014), information systems (e.g. Nunamaker Jr. et al., 2015), information visualisation (e.g. Preim, Ropinski, and Isenberg, 2018), and Ubicomp (e.g. Hazlewood, Stolterman, and Connelly, 2011). When considering in-situ research in the domain of ambient displays, it was concluded that there are no methodological advices on how to conduct such research in longitudinal enterprises. This argument built on the following observations:

- Ambient displays warrant methodological development as their user experience "is radically different from the traditional focused task oriented user situation" (Hazlewood, Stolterman, and Connelly, 2011, p. 877). Research that explores new evaluation methods that particularly account for this special requirement is necessary (Hazlewood, Stolterman, and Connelly, 2011; Shelton and Nesbitt, 2017). Approaches already utilised such as heuristic evaluations (e.g. Mankoff

Figure 2.5: The WaveWatch display deployed in a university office (Shelton and Nesbitt, 2017).

et al., 2003) building on Nielsen's heuristics (Nielsen and Molich, 1990), short-term in-situ pilot studies (e.g. Obermair et al., 2008), uncontrolled experiments (e.g. Lee et al., 2012), case-orientated field trials (e.g. Dadlani, Markopoulos, and Aarts, 2009), and evaluation frameworks (e.g. Holmquist, 2004) seem to account for the complexity of such endeavours rather insufficiently.

- While investigating selected field deployment studies (Memarovic, Elhart, and Rubegni, 2016; Ojala et al., 2012; Peltonen et al., 2008; Rogers et al., 2010)—Figure 2.5 demonstrates the so-called *WaveWatch* solution (Shelton and Nesbitt, 2017)—it was observed that authors do not provide any rationale as to why their evaluations were carried out in the way illustrated. This finding somewhat corroborated the issue of lacking methodological development.

- Large display research seems to lack existing general theories as demonstrated in the related domain of public displays (Alt et al., 2012).

- Furthermore, there seems to be a focus on technology rather than on how operation relates to people's everyday lives (Matthews, Rattenbury, and Carter,

2007). In fact, ambient display research scarcely includes social aspects such as stakeholder behaviour (Messeter and Molenaar, 2012).

- Finally, there is a lack of long-term ambient display field deployment research, which was revealed in the context of a recent literature review on ambient displays (Börner, Kalz, and Specht, 2013).

2.4 Limitations of Existing Knowledge Summary

In an effort to summarise the different research gaps identified throughout the non-committal phase, this section collates the findings according to the corresponding review stages. This overview demonstrates how literature work incrementally informed and shaped the problem area.

Pre-Existing Knowledge Included knowledge from preliminary literature reviews (2010–2013) and a total of five resulting German publications (Barnkow, Schwarzer, and von Luck, 2012, 2013; Schwarzer et al., 2013; Schwarzer, Barnkow, and von Luck, 2013; Schwarzer and von Luck, 2012).

- Further research exploring large display deployments in authentic environments—also emphasising on the process of designing, customising, and prototyping these solutions—would apparently advance existing knowledge.

***Literature review 1*: Exposé** Primarily resulted in a more narrowed research focus and a German publication (Schwarzer, Draheim, and von Luck, 2015) in addition to an English one (Schwarzer et al., 2016).

- Empirical research in industrial settings, including factors such as shared environments and different sizes of audience groups, seem to manifest fertile areas for further investigations.

- In general, it was concluded that there is a predominance of large display research in an academic context.

- Also, the factors relating to the adoption and success of large displays are scarcely investigated as common guidelines are still absent.
- Research is also warranted to investigate large displays in a broadening range of physical environments to bridge the gap between online and offline worlds.
- Finally, a strong research emphasis on information awareness was revealed. Future studies, which particularly focus on collaboration and communication challenges, seem to be promising directions.

***Literature review 2*: Pre-Review** Mainly resulted in a systematic literature review with two iterations in 2016 (initial conduct) and 2017 (revision). In combination, both iterations contributed towards a 2017 publication (Schwarzer et al., 2017).

- Future research on large displays may also investigate what constitutes relevant information and how it should be communicated.
- There is also a call for more longitudinal studies to overcome phenomena such as the Hawthorne effect.
- Research is also warranted regarding the adoption of visualisation tools in the industry as only a few adopted examples exist.
- Lastly, it was revealed that communication in ASD requires more research.

***Literature review 3*: The Novelty Effect** This review was an inherent part of a co-authored publication (Koch et al., 2018) and was also a first stepping stone towards *Literature review 4*.

- There is no existing formal or comprehensive definition of the novelty effect. Generally, research on the novelty effect in CSCW and HCI research is in its early stages. Consequently, future research conducted in this vein would contribute towards mitigating this lack of knowledge.
- The literature fails to provide sufficient tools that allow the examination of the novelty effect. For that reason, research as a means of investigating this effect further is required.

- Research misses mechanisms to cope with the novelty effect on a methodological level. Fundamentally, research that envisions directions to deal with this effect more holistically is required.

***Literature review 4*: In-Situ Research** This review continued the shift towards looking at the research problem area through a more methodological lens. This most recent development was reflected in a 2019 publication (Schwarzer et al., 2019).

- Ambient display research still lacks longitudinal field deployments. It seems that any study conducted in this light would contribute valuable knowledge to the community.
- Social aspects received little attention and there is a technology-related focus observable. Consequently, research that widens the scope of investigation by explicitly including social aspects would add valuable contributions.
- Fundamentally, ambient display research lacks methodological development. Thus, research that elaborates methodological guidance would affect the domain to a substantial extent.

2.5 Determining the Primary Research Aim

Attention is now drawn to the primary aim of this research. Again, the non-committal phase not targets at generating research questions (Urquhart and Fernández, 2013). Generally, this research commenced with what Glaser (1992, p. 22) refers to as an "abstract wonderment of what is going on" rather than with pre-defined research questions. In fact, research questions in GT emerge as the research process progresses (Stol, Ralph, and Fitzgerald, 2016). This stance on approaching a research problem is also leveraged in other doctoral dissertations which utilise classic GT methodology (e.g. Hunter, 2014; Mathison, 2012; Ross, 2016).

Fundamentally, the research focus evolved over time and the problem area successively sharpened as it was progressively found that existing knowledge is more substantially limited than had been initially anticipated. This circumstance is exemplified by

This study seeks to propose a substantive theory of ambient displays in the wild by shedding light on a longitudinal investigation of a custom ambient display solution in an authentic, co-located, and matured ASD environment.

Figure 2.6: The initially formulated research aim.

the apparent challenge of bringing methodology to the field of ambient display research. The following puts forth two research gaps which this research project seeks to advance. It is started with an introduction to the initial research focus (labelled *Research gap 1*) in Section 2.5.1 and it is then continued with the evolved research emphasis (labelled *Research gap 2*) in Section 2.5.2. Both research gaps were selected as they seemed the most far-reaching in terms of their contribution value.

2.5.1 *Research gap 1*: Long-Term Findings

This chapter has made the argument that research fails to present long-term findings of ambient displays in authentic, co-located, and matured ASD environments. Although these devices allegedly encourage communication, collaboration, awareness, and information sharing, only a few studies have attempted to scrutinise them more thoroughly in real-world scenarios. *Research gap 1* is aimed at the lack of knowledge regarding ambient displays on a findings level as seemingly any long-term endeavour would contribute valuable insights. Accordingly, the research began in 2015 and the research aim was initially framed (see Figure 2.6). The following research objectives were correspondingly defined:

1. To cultivate the already-established collaboration with the project partner. This objective foresaw tasks such as repeatedly and proactively talking to the project partner to, for example, early indicate changes in the toolchain (e.g. updates and obsolete tools).

2. To cope with issues surrounding operational feasibility. Fundamentally, it was committed to the challenge that research prototypes must be robust and typically not withstand daily usage in authentic contexts (Nunamaker Jr. et al., 2015; Siek et al., 2014). Consequently, this research objective drew attention to aspects that

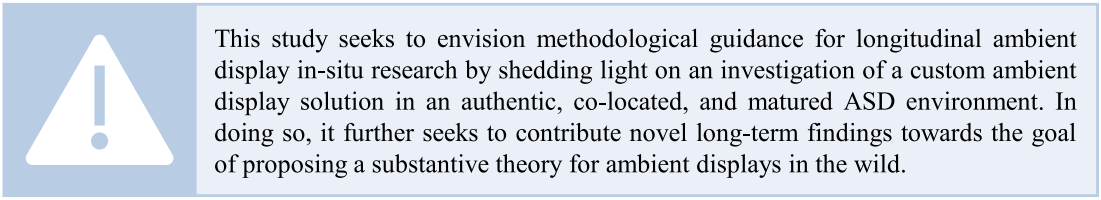

Figure 2.7: The revised formulation of the research aim.

embodied a potential threat to the operational state of the systems. Therefore, the expected relevant tasks were to, for instance, continuously maintain the software application (see Section 3.4.1) but also to document certain events in order to pinpoint them later during analyses (e.g. hardware failures), if required.

3. To develop a conceptual and theoretical understanding of how people utilise the Ambient Surfaces by generating a substantive theory.

2.5.2 *Research gap 2*: Methodological Development

The second research gap widens the scope of *Research gap 1* as it is targeted at the lack of methodological development in ambient display research. Fundamentally, *Research gap 2* refers to issues that underlay and are manifested in *Research gap 1*. Consequently, it draws attention to concerns on a methodological level. Accordingly, the primary research aim was restated (see Figure 2.7). In terms of research objectives, however, the restatement of the primary research aim led to the introduction of no further specific research objectives that were required to aid the formulated purpose.

2.6 Summary

The above-mentioned has addressed the topic of literature work and its shifts in emphases throughout the present classic GT study. It reflects a practical approach to literature work in a classic GT research enterprise. The chapter set out with Section 2.2, which drew attention to a contemporary and contentious debate on the timing of literature work in GT methodology. Section 2.3 then continued with an elaboration on all major literature stepping stones during the non-committal phase. While Section 2.4 collated limitations of existing knowledge, Section 2.5 put forth the primary research aim. Two research gaps were highlighted that this research seeks to advance:

firstly, the scarce existence of long-term findings of ambient displays in practice (i.e. *Research gap 1*); and secondly, the lack of methodological guidance for such research enterprises (i.e. *Research gap 2*).

The remainder now continues with Chapter 3, which concentrates on the foundations underlying the present research in an attempt to advance on both research gaps.

Chapter 3

Methodology and Research Design

> "People think about what they are learning *while* [emphasis as in original] they are learning, and GTM [grounded theory method] turns that tendency into a scientific strength through methodological underpinnings ..., guided by principles of constant comparison and theoretical sampling."
>
> —Muller (2014, p. 273)

3.1 Introduction

The organisation of this chapter was largely affected by the work of Saunders, Lewis, and Thornhill (2009), and Sekaran (2003). While the former's work contributed a layered illustration that draws attention to methodological underpinnings that ought

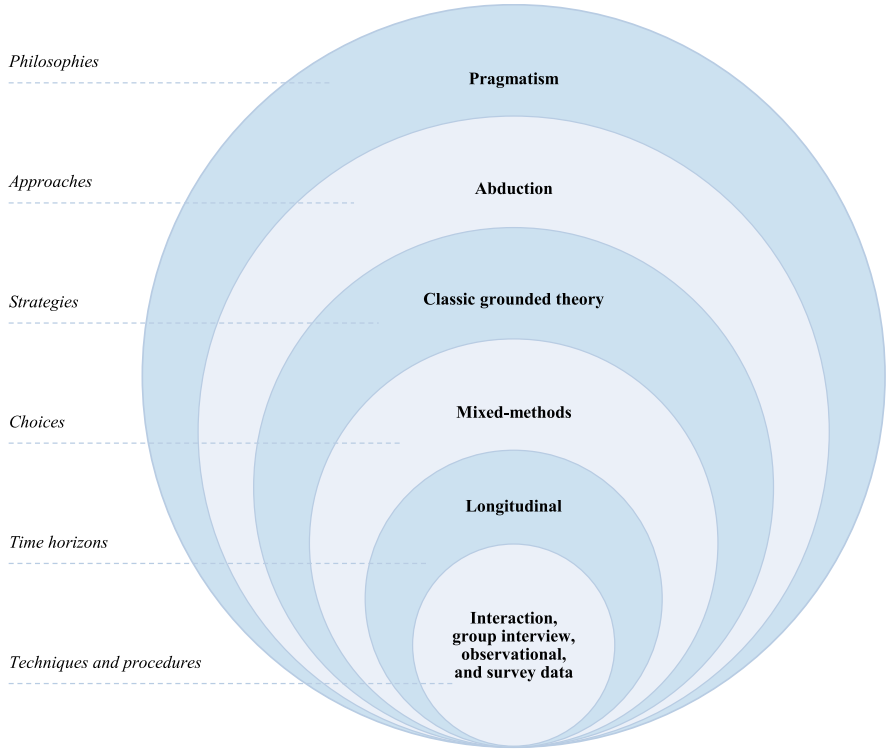

Figure 3.1: A layered visualisation based on the research *onion* from Saunders, Lewis, and Thornhill (2009) to visually present the choices made in this study.

to be considered in a research enterprise, the latter's was consulted for general guidance to outline a research design. Section 3.2 returns to these elements and elaborates on them thoroughly. The remainder then continues with an introduction to the research setting in Section 3.3. Subsequently, Section 3.4 presents the custom ambient display solution utilised (i.e. the Ambient Surfaces). Afterwards, Section 3.5 discusses the role of the researcher and Section 3.6 puts forth ethical considerations. Finally, Section 3.7 summarises this chapter.

3.2 Research Foundations

The foundations that underlie the present research are now introduced (see Figure 3.1). Therefore, the philosophical stance[1] and the approach to scientific reasoning are firstly elaborated on (see Section 3.2.1). The selected research strategy is then described (see Section 3.2.2). Subsequently, the following continues with the choices made relating to

[1]This chapter does not introduce all known philosophical positions. In this regard, the reader is referred to other work such as from Crotty (1998).

the data (see Section 3.2.3) and then addresses the time horizon of this research (see Section 3.2.4). Finally, the different techniques and procedures utilised are covered (see Section 3.2.5).

3.2.1 Philosophy of Pragmatism

This section describes the first two elements of a research enterprise—the philosophical stance (i.e. pragmatism) and the approach to scientific reasoning (i.e. abduction)—as well as the motivation as to why both were chosen for the present research.

3.2.1.1 Rationale

Pragmatism is one of four major philosophical stances in social and behavioural sciences, including constructivism, positivism, and postpositivism (Tashakkori and Teddlie, 1998). As a research paradigm, pragmatism follows the general notion of a basic belief system. These systems "must be accepted simply on faith (however well argued); there is no way to establish their ultimate truthfulness" (Guba and Lincoln, 1994, p. 107). Following Guba and Lincoln (1994), one typically chooses a research paradigm based on three interconnected questions targeted at ontological, epistemological, and methodological issues. Principally, research paradigms stand in contrast regarding these three questions, which is more thoroughly illustrated, for instance, in tabular overviews provided by Tashakkori and Teddlie (1998), and Guba and Lincoln (1994).

The notion of pragmatism can be vividly summarised by the following quote: "Study what interests and is of value to you, study it in the different ways that you deem appropriate, and use the results in ways that can bring about positive consequences within your value system" (Tashakkori and Teddlie, 1998, p. 30). More formally, when considering the work of Cherryholmes (1992) and Morgan (2007), Creswell (2014) summarises pragmatism as follows (to name but a few):

- It does not commit to any philosophy and reality—it does not perceive the world as an absolute unit.
- Pragmatism enables researchers to freely select methods, techniques, and procedures to obtain knowledge.

- It lets researchers consider what and how to investigate based on intended consequences.

Pragmatism is considered as a practical and applied research philosophy and invites both deductive and inductive reasoning for scientific discovery (Tashakkori and Teddlie, 1998). A thorough introduction to both approaches can be found elsewhere (e.g. Popper, 1959), while the following concentrates on abductive reasoning. Abduction was coined by Charles Sanders Peirce and strongly underlies the philosophy of pragmatism (Peirce, 1935). Mcauliffe (2015) provides a recent reflection on Peirce's various writings. Accordingly, abduction follows the notion of guessing, meaning that proposed hypotheses may end up not meeting the criteria for actual testing. In relation to both induction and deduction, abduction provides a means to generate and choose hypotheses for testing purposes. Peirce (1935) describes abduction as a process that forms explanatory hypotheses. In doing so, it is reportedly the only way to extend existing knowledge, as induction simply determines a value and because deduction deals with the consequences of hypotheses. He summarises all three ways of reasoning as follows: "Deduction proves that something *must* be; Induction shows that something *actually* is operative; Abduction merely suggests that something *may be*" (Peirce, 1935, p. 106, emphases as in original).

3.2.1.2 Motivation

The fundamental notion of pragmatism felt appealing as regards the two research gaps illustrated (see Section 2.5). Both arguably exemplify the overall exploratory nature of this research on both a findings and methodological level. Given this broad starting point, a practical approach seemed most promising. Consequently, philosophical stances which lean largely towards deductive reasoning were immediately excluded in the process of determining a philosophical position. Simultaneously, such positions do not sufficiently explore human behaviour and largely focus on control (Hunter, 2014). Both aspects were central during the decision-making process as it was intended to understand how people were utilising the custom ambient display solution (see Section 3.4) in an uncontrolled authentic environment (see Section 3.3). Yet, also a commitment to

a mostly inductive approach felt less suitable for the present study. It was hardly feasibly to foresee the development and focus of the research. Such a decision would have diminished the chance of approaching questions surrounding generalisability (Hunter, 2014). This consideration was exemplified by the fact that there is a multitude of data collection methods leveraged in large display research (Alt et al., 2012)—including sensor data, questionnaires, and observations.

Similarly, the notion of abductive reasoning felt most appealing. However, that is not to say that the other two types of reasoning were not an expected part of the research. Principally, the literature indicates that assigning reasoning approaches to particular philosophical stances is somewhat misleading and of no practical value (Saunders, Lewis, and Thornhill, 2009). Nevertheless, the general philosophical position was to see scientific inquiry as a continuum (Tashakkori and Teddlie, 1998), and it seemed that abduction represented the notion of this research the best.

3.2.2 Classic Grounded Theory

This section continues with the research strategy. It sets out with a brief historical background of classic GT and subsequently continues with a description of the methodology's rationale. Finally, the following elaborates on the motivation as to why classic GT was applied to this research.

3.2.2.1 A Brief Historical Background

According to Glaser (2008), GT finds its roots in work on methodology for quantitative studies from the 1950s (e.g. Lazarsfeld, 1955). Similarly, GT was an inductive response to predominant hypothetico-deductive research approaches (Glaser and Strauss, 1967; Morse et al., 2009; Stol, Ralph, and Fitzgerald, 2016). In the 1960s, Barney G. Glaser and Anselm L. Strauss published a seminal book on GT methodology titled *The Discovery of Grounded Theory* (Glaser and Strauss, 1967).

Over the last decades, GT has developed a traceable lineage beyond this seminal publication (Morse et al., 2009). Since the early 1990s, it has evolved from its origins into two major streams that were labelled by Stern (1995) as *Glaserian GT* (e.g. Glaser, 1978)—respectively called *classic GT* (Stol, Ralph, and Fitzgerald, 2016) or *classical*

GT (Adolph, Kruchten, and Hall, 2012)—and *Straussian GT* (e.g. Strauss, 1987). Other scholars, who further developed GT methodology, are summarised under the term *second generation* (Morse et al., 2009), whereas Kathy Charmaz (Charmaz, 2000, 2006, 2014), with her variant called *Constructivist GT*, initiated this shift (Bryant, 2009). Further contemporary representatives are Phyllis Noerager Stern (Stern, 1995), Juliet Corbin (Corbin and Strauss, 2008, 2015; Strauss and Corbin, 1998), Barbara Bowers and Leonard Schatzman (Bowers and Schatzman, 2009; Schatzman, 1991), as well as Adele E. Clarke (Clarke, 2003, 2005; Clarke, Friese, and Washburn, 2015).

Nowadays, GT methodology varies and has evolved. It will evolve further, affected by developments such as the recent interest in computer-based analyses (Morse et al., 2009).

3.2.2.2 Rationale

Morse et al. (2009) provide an overarching introduction to GT methodology. Accordingly, GT generally provides a means to think about and theorise from data—a conceptualisation process that results in a theory about a substantive area that the researcher produces. This inherent nature can neither be standardised nor does it embody a prescribed method with formulaic techniques to calculate an outcome. Strategies to prepare and gather data assist in the process of theorising but do not make the methodology. GT research is empirical, not logical; it provides generality on a conceptual, not a unit level (Glaser, 1998). As GT is performed by the individual researcher, it is neither conducted in the same way nor is a GT study replicable (Heath and Cowley, 2004; Morse et al., 2009). Central to GT methodology is the fact that it leverages the lay human capability of inquiry, thinking, and knowing (Glaser, 1998; Morse et al., 2009; Muller, 2014). GT seeks to formalise this cognitive process into a quality process to generate new insights and theories (Muller and Kogan, 2012).

Glaser (2008) elaborates that theory is generated conceptionally, abstract of attributes such as time and place, and does not draw on extent theory prior to research. Initially, GT research only requires a general area of interest and an open mind for emerging patterns. The overall aim is "to determine which or what is actually going on" (Glaser, 2008, p. 5)—in one form or the other, the starting point in every GT

study (Glaser, 1978; Glaser and Strauss, 1967). GT methodology proposes grounded hypotheses, not facts (Glaser, 1978, 2008). Generally, it strives towards discovering not "*the* theory, but *a* theory" (Heath and Cowley, 2004, p. 149, emphases as in original), while "a theory should be able to explain what happened, predict what will happen and interpret what is happening in an area of substantive or formal inquiry" (Glaser, 1978, p. 4). A generated theory explains how its conceptual elements relate to one another (Glaser, 1998).

Variations in GT arise from epistemological stances, methodological strategies, assumptions about what constitutes theory, and lastly conceptional directions (Morse et al., 2009). However, Heath and Cowley (2004) note that methodological aspects are considered to be the main source of the divergence between GT scholars. The first apparent divergence occurred during the 1990s (Kelle, 2005), where Glaser (1992) criticised both Strauss and Corbin (Strauss, 1987; Strauss and Corbin, 1990) for attempting to force themes on data (i.e. opposed to emergence). Strauss and Corbin propose the use of a specified theoretical framework, whereas Glaser stresses that coding must be conducted ad hoc on the basis of more or less implicit knowledge (Kelle, 2005). Whereas Glaser is seen to remain faithful to the classic mode of GT methodology, the work from Strauss and Corbin (1990) is considered to be a reformulation of this classical approach (Annells, 1997).

However, Glaser (1998) emphasises that arguing the methodology's virtues in terms of opposing positions (e.g. emergence versus forcing) is a rhetorical wrestle which, in his view, is a waste of time, while choosing GT is all that is necessary. Kathy Charmaz summarises this issue as follows: "Whether a particular variant of grounded theory has developed, shifted, eroded, or irrevocably changed[;] grounded theory depends on what you define as the genuine method and on your epistemological perspective" (Morse et al., 2009, p. 136).

3.2.2.3 Motivation

The motivation to select GT methodology—and classic GT in particular—arose from philosophical reflections (see Section 3.2.1) and the problem area itself (see Section 2.5). Aspects concerning GT methodology in general were:

- GT embraces a pragmatist philosophy and an abductive lens of reasoning. As Bryant (2009) notes, this gets particularly exemplified by the concept of *theoretical sensitivity* in classic GT (Glaser, 1978). Theoretical sensitivity refers to a researcher's capability (i.e. knowledge, understanding, and skill) to generate theory (Glaser, 1992). While it is an essential part of GT methodology, it is difficult to be described and, simultaneously, it is a challenge to explain how it can be developed (Bryant, 2009). Bryant (2009) further explains that a pragmatic perspective draws attention to the core strength of GT (i.e. discovery of new insights and theories) and simultaneously casts aside many issues which separate GT scholars with their individual interpretations of the methodology.

- GT allows social phenomena, independently of a particular research discipline, to be scrutinised (Glaser and Strauss, 1967). It therefore assists in coping with the issue that socially embedded technology cannot be investigated without its social components (Bjørn and Boulus-Rødje, 2015).

- Furthermore, GT enables to deal with the dynamic nature of field deployments, which is deemed challenging and may require changes in the data collection procedure (Siek et al., 2014). GT does not ask for any sort of data to be preconceived, but to let the data emerge and openly choose the most appropriate data collection method (Glaser, 1998).

- As long-term in-situ research is such an unexplored territory (Börner, Kalz, and Specht, 2013; Hazlewood, Stolterman, and Connelly, 2011; Preim, Ropinski, and Isenberg, 2018), scarce theoretical guidance arguably existed to pose any initial research questions or hypotheses. Additionally, the field of large display research is lacking in general theories (Alt et al., 2012). GT follows the notion of commencing any research open-mindedly without any preconceived problem statements (Glaser, 1998).

- *Proof-of-use* research—inquiries aimed at topics surrounding the complexity of operational feasibility—generally faces the issue of externalising and codifying a researcher's tacit knowledge (Nunamaker Jr. et al., 2015). GT provides a means

to report a researcher's own experiences and in doing so increases traceability and credibility (Boeije, 2002). It situates study participants' actions and interpretations in the relevant circumstances and thus makes them explicit (Morse et al., 2009).

Finally, the section concentrates on motivational aspects that led to the selection of classic GT:

- Classic GT invites both quantitative and qualitative methods as it is considered as a general methodology (Glaser, 1998). In fact, Glaser and Strauss (1967) and Glaser (1998, 2008) consider all kinds of data as valuable in the process of generating theory (e.g. documents, magazines, and interviews). In comparison to other GT variants such as Straussian GT and Constructivist GT, classic GT suits the requirements of field deployment research arguably better, as—again—typically a mixture of different methods is utilised in such enterprises (Alt et al., 2012).

- Bryant (2009) summarises that Straussian GT, as opposed to classic GT, fails to incorporate the idea of abduction, which resulted in notable allegedly justified criticisms from other authors, including Glaser (1992).

- Lastly, classic GT's tendency to lean towards emergence seemed more appealing. This less directive characteristic and the methodological openness were also relevant to other researchers throughout their methodological decision-making process (e.g. Ross, 2016; Stray, Sjøberg, and Dybå, 2016).

3.2.2.4 Trustworthiness

According to Lincoln and Guba (1985), the issue of trustworthiness surrounds the topic of how an audience is persuaded to pay attention to and take account of research. Essentially, quantitative and qualitative tenets bring their individual sets of criteria to draw on trustworthiness. While in quantitative research the criteria *internal validity*, *external validity*, *reliability*, and *objectivity* are used, qualitative research lays a focus on *credibility*, *transferability*, *dependability*, and *conformability*.

GT addresses bias through comparative analyses as bias in any form (i.e. personal or method) reportedly reconciles once the underlying causes of variation are discovered (Glaser and Strauss, 1967). Since GT is considered a general methodology, it comes with a unique means to reflect on the trustworthiness of the research (Hunter, 2014). To this end, Glaser (1978, 1998) defines the criteria *fit*, *relevance*, *work*, and *modifiability* as the main sources of trust:

- Fit: concerns whether concepts adequately express the pattern in the data. Here, fit is another word for validity.
- Relevance: means a core concept's grab—it fits and works. In doing so, the core concept works both within the substantive area and to other researchers, participants, and practitioners. What emerges with fit has relevance.
- Work: addresses a theory's explanatory power. What emerges with fit and relevance does also work—a theory and its elements relate to what is actually going on in a substantive area.
- Modifiability: refers to the capability of a theory to be readily modifiable as new data emerges.

However, these criteria are not intended to be utilised from the outset of a research endeavour—instead, they are applied to the resulting theory (Hunter, 2014). Chapter 5 therefore reconsiders these criteria and discusses them bearing this research in mind.

3.2.3 Mixed-Methods Approach

There is no simple answer to the question of what data collection and analysis techniques should be applied in a research enterprise (Saunders, Lewis, and Thornhill, 2009). Research choices embody the notion of how one chooses to combine qualitative (i.e. a synonym for non-numeric material) and quantitative (i.e. a synonym for numeric material) data in a study (Saunders, Lewis, and Thornhill, 2009).

In approaching this question, earlier decisions made throughout the selection of the underlying philosophy (see Section 3.2.1), the research strategy (see Section 3.2.2), and the research gaps (see Section 2.5) were essential. To summarise, the general notion was

to sustain openness with respect to the formulated research problem. A mixed-methods approach was chosen for this research as both qualitative and quantitative data collection techniques as well as analysis procedures were intended to be leveraged (Saunders, Lewis, and Thornhill, 2009). This decision built on the following considerations: firstly, there is an observable variety of different data collected in large screen research (Alt et al., 2012); secondly, the associated virtues of a mixed-method approach felt compelling considering the research problem at hand. For instance, Bryman (2006) highlights aspects such as triangulation (i.e. one source corroborates the other), completeness (i.e. a combination of sources is more comprehensive), and credibility (i.e. enhancement of findings integrity) as reported attributes to favour such a position. In combining both data sources in tandem, it was intended to increase the possibility of unanticipated research outcomes (Bryman, 2006). Finally, in GT research it is generally encouraged to utilise a diversity of data to generate theory (Glaser and Strauss, 1967).

3.2.4 Time Horizon

Saunders, Lewis, and Thornhill (2009) emphasise that the decision for a time horizon is independent of, for instance, selected methods and a research strategy. Generally, they introduce two options: firstly, snapshots taken at specific points in time, referred to as *cross-sectional* research; secondly, a series of snapshots—or diary—as a representation for a selected time period (i.e. longitudinal research). As elaborated on in Section 2.5, this research seeks to contribute findings from a longitudinal enterprise. It was aimed at keeping both Ambient Surfaces operational for a couple of years. However, whether people kept utilising the Ambient Surfaces, was a somewhat open question at the beginning—the threat of falling into disuse is also indicated in the literature (Huang et al., 2006). In the end, data was gathered over the course of 5 years (i.e. between 2014 and 2019). Iterations of data collection and analysis were affected by a multitude of issues throughout the research, which sometimes interrupted these activities and accounted for time-intensive tasks. For example, several revisions to the Ambient Surfaces' software solution were released and occasionally critical software issues had to be resolved (e.g. a third-party component utilised between 2014 and 2016 repeatedly resulted in software crashes due to instability issues).

3.2.5 Techniques and Procedures

Evidently, conducting GT with qualitative data (e.g. Glaser, 1978) is in stark contrast to GT with quantitative data (Glaser, 2008). Although GT methodology is introduced to work with any type of data (Glaser, 1998), apparently there is only the aforesaid seminal book on using quantitative data available. Yet, this book solely elaborates on techniques and procedures to analyse data collected elsewhere (i.e. secondary data in the form of large surveys).

This section firstly illustrates a synthesised overview of the different conceptual steps in GT. To this end, an emphasis is placed on outlining how techniques and procedures are utilised with both types of data. The section then continues with the approach in this work, which is an adoption of this synthesis.

3.2.5.1 From Data to Theory

If not otherwise indicated, the synthesis builds on four books (Glaser, 1978, 1998, 2008; Glaser and Strauss, 1967). While the three older books contributed fundamental insights regarding the methodology and the processing of qualitative data, the more recent work on quantitative data was analogously consulted for this kind of material. Figure 3.2 shows the different levels (labelled *Level 1* to *Level 4*) of conceptualisation in GT methodology. It shall now continue with an explanation of these levels and the corresponding activities.

General Analysis Approach GT methodology is fundamentally based on a third-level conceptual perspective analysis model (i.e. *Level 3*). Prior to this stage, there is data on one end of the continuum (i.e. *Level 1*) and there is data completeness at the other end (i.e. *Level 2*). Data completeness is based on *theoretical completeness* that embodies the final stepping stone in saturation, meaning "that the researcher can explain why most action goes on in a substantive area with his grounded theory" (Glaser, 1998, p. 86). Generally, data saturation in GT is not limited to a particular threshold such as the number of interviews, but to striving towards theoretical completeness or to the researcher's own exhaustiveness (e.g. financially or physically). The goal of analyses is to generate a conceptual theory, not conceptual coverage that is represented by

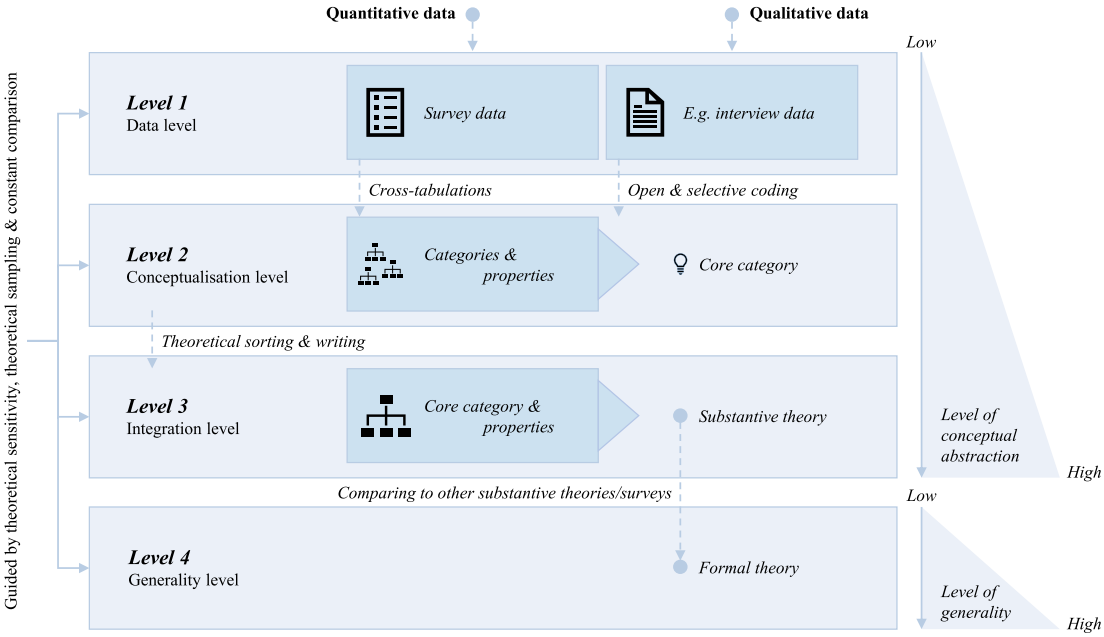

Figure 3.2: A synthesis of the three levels of the GT analysis process with both quantitative and qualitative data. In addition, the illustration indicates the optional fourth level of a GT enterprise (i.e. formal theory).

its generated core theme. This core theme does not necessarily have to be a social process. If the researcher desires, a substantive theory can subsequently be generalised to create formal theory (i.e. *Level 4*). The analysis process is denoted as being systematic as rules are rigorously applied in each step. Doing GT is described to be subsequent, sequential, simultaneous, serendipitous, and scheduled (denoted as the *five S's*), while data in GT can be collected at any time. However, GT is often scheduled. For instance, throughout the procedures of sorting and writing (i.e. *Level 3*), the researcher can leave anytime to follow up on other relevant topics.

Units of Interest Four terms are of central importance for analyses: the *core category* (i.e. the core theme) and—as indicated in Section 1.6—the category, the property, as well as the indicator. A category conceptually "captures the underlying patterns in the data" (Glaser, 1998, p. 135). A property represents a specific concept of a category, meaning it is conceptually subordinated to a corresponding category. Together both constitute a *conceptual code* that provides an abstract view within the scope of indicators (i.e. specific empirical findings within the data); it links theory to data. Principally, GT is based on a concept-indicator model which directs conceptual coding based on empirical indicators (see Figure 1.1). To this end, indicators are

constantly compared in terms of their similarities and differences to build an underlying uniformity that finally results in categories and their properties. Indicators are interchangeable, meaning two aspects foremost: firstly, categories and their properties pattern out regardless of how or where one commences the analysis; secondly, they individually contribute enriching perspectives on the same idea (e.g. a category). A generated theory is applied by the reversibility of interchangeable indicators, meaning that the very indicators that were used to create concepts allow concepts to specific empirical findings to be linked back. Finally, there is the core category. It is the conceptual code which relates to most other codes and accounts for most of the behaviour in the substantive area. Generally, categories can be organised hierarchically, including the core category at the top with the other categories below it.

Constant Comparison and Theoretical Sampling Aside from theoretical sensitivity, two further level-overreaching pillars in GT research are *constant comparison* and *theoretical sampling* (see left side in Figure 3.2). Although GT variants differ, constant comparison and theoretical sampling constitute the methodology's foundations (Morse et al., 2009).

Constant comparison is an approach to both qualitative and quantitative data analysis. It introduces a rationale to simultaneously code and analyse to systematically generate theory. In doing so, it is concerned with "plausibly suggesting ... many categories, properties, and hypotheses about general problems" (Glaser and Strauss, 1967, p. 104). For example, in Chapter 4 interaction data is constantly compared to create first hypotheses about latent patterns in the data (e.g. to reveal times of day with the strongest usage). Constant comparison focuses on the generation of codes. It stands in contrast to other contemporary approaches: firstly, it does not aim to crudely convert data in a quantifiable form (cf. provisional testing); secondly, it does not supplant the skills and the impact of the individual analyst in the process of generating theory (cf. quantitative analysis); and thirdly, it does not attempt to corroborate universality or proof of a suggested cause or property (cf. analytic induction).

The concept of theoretical sampling goes hand in hand with constant comparison. It is the prime mover for coding, collecting, and analysing activities with theoretical

completeness in mind. While during theoretical sampling one is constantly comparing data for its meaning, constant comparison unfolds the sense behind this meaning. The necessary amount and kind of sampled data cannot be defined in advance. Rather, it is directed by an emergent theory and further develops its emergence by determining where to collect data next, what for, and why. Considering the example from above, it was at some point realised that interaction data was limited in indicating the underlying reasons for prevalent patterns in the data hence data stemming from other sources (e.g. observations) was sampled and cross-compared throughout analyses. Generally, theoretical sampling strives towards yielding data saturation by constantly focusing and delimiting the study. However, there are circumstances that may delimit the overall sampling procedure such as restricted time resources (Glaser, 1978) or the decision to utilise readily available secondary data sources such as surveys (Glaser, 2008). Data sampling in GT is ideational (i.e. a conceptual about), not representative (i.e. a numbered about). As a result, fact in GT comes in the form of indicators to code ideas (i.e. categories and their properties).

Data saturation in GT builds on the interchangeability of indicators, meaning that newly collected data empirically differs but, at some point, repeatedly links to the same and existing categories and properties—sampling of new data becomes useless. The purpose is to unveil theoretical meaning hence saturation and not distribution (e.g. counting the occurrences of a particular category). However, data saturation is described as being a "mysterious" process in GT (Aldiabat and Navenec, 2018, p. 258).

From *Level 1* to *Level 2* The overall aim in this stage of research is to transcend the researcher's empirical view (i.e. *Level 1*) to a conceptual level (i.e. *Level 2*). For the sake of clarity, in this section, the rationale is described individually for both quantitative and qualitative data.

Qualitative Data Qualitative GT commences with *open coding*. Open coding means that an individual is literally coding everything in order to generate categories and their properties (i.e. conceptual codes). The researcher is guided by three questions (Glaser, 1998, p. 123): firstly, "What is this a study about?"; secondly, "What

category does this incident indicate?"; and finally, "What property of what category does this incident indicate?". Indicators are pinpointed by reading material line by line and are found in phrases, sentences, or whole paragraphs. This may also lead to coding of something that might not be directly stated. In this early stage of the research, the researcher mostly engages in what is called *substantive coding* (i.e. legitimising), meaning that the individual is creating several conceptual codes that image a substantive area. Substantive codes are the conceptual building blocks of the emergent theory. It is aimed at as few substantial codes as possible for the greatest variance in imaging a substantive area. The researcher also starts to create *theoretical codes* (i.e. looking for consequences). Theoretical codes describe how substantial codes stand in relation to one another in the form of interrelated and multivariate hypotheses. However, these codes are typically created later throughout the sorting procedure (see next section).

At some point during open coding, the researcher realises that some substantive codes are more relevant than others—i.e. the core category of a study is starting to emerge and, subsequently, data collection and analysis activities focus on this pivotal point (i.e. *selective coding*). The switch between open coding and selective coding occurs almost automatically as the core category is predominantly represented in the data. When compared to open coding, this delimits the research substantially. While it is generally advised to concentrate on just one core category, it is also indicated that one should not become selective too quickly. Open coding comes to an end when all data fits—theoretical completeness becomes prevalent.

Throughout this stage of research, one crucial tool of GT with qualitative data is introduced in the overall analysis process: *memos*[2]. Memos are a medium (e.g. handwritten or typed documents) that is free, emergent, non-visible, and private. They do not underlie strict guidelines other than to informally capture ideas for the emergent theory as they occur. Essentially, they are the theorising writing about substantive codes and how they theoretically relate to one another. They keep track of the emergent theory and its overall complexity. Maturing memos progressively delimit a study and saturate categories and their properties.

[2]Examples of memos created in this work follow in Section 3.2.5.2.

Quantitative Data Memos, a crucial element in qualitative GT, interestingly find no mention in the context of analyses for quantitative data. Here, two-variable and three-variable cross-tabulations are used to guide the emergence of a theory. Yet, it does not become clear as to how one should proceed to keep track of the emerging theory in quantitative GT. For instance, in analysing survey data, the researcher can finally end up with hundreds of cross-tabulations. However, cross-tabulations seemingly embody the equivalent counterpart to open and selective coding practices. Generating a core category (e.g. *Scientific professional recognition*) in quantitative GT is based on the idea of substruction, meaning that one is conceptually analysing its dimensions (e.g. *Publications* or *Being footnoted*). The researcher is looking for indicators of these dimensions in the survey data and constructs a *crude index*. Crude indices are "either a single questionnaire item or a series of items summed into an index" (Glaser, 2008, p. 42). They suffice when indicating the concepts of an emerging theory. Items typically come in the form of Likert scales and stem from the area of interest. The researcher is literally playing with a set of different items to find the most suitable ones.

For the core category, a crude index with at least two items is created and is dichotomised in a high and low range of values to create comparable groups. This produces relationships between interchangeable survey items. Generating theory with quantitative GT comes down to investigating general directions in relationships (i.e. a positive and negative relation), not precise measurements. The core category emerges roughly the same as it does in qualitative GT: it emerges as relevant at some point, meaning that a whole series of items is consistently related to it. If the core category is found and tested, the researcher then engages in two-variable cross-tabulations to indicate the first hypotheses of the emergent theory. To this end, the researcher makes use of *consistency indices*. Consistency indices are clusters of relationships (i.e. the first variable)—lists of single items that point to the same category—which are related to the index of the core category (i.e. the second variable). Table 3.1 exemplarily illustrates a two-variable cross-tabulation relating the crude index *Motivation to advance knowledge* to a consistency index (i.e. the list of additional working hours cases). According to this cross-tabulation, for the more hours added to a working week, "the highly motivated scientist spends more time on both professional and organisational activities"

Table 3.1: An example of a two-variable cross-tabulation used by Glaser (2008).

Consecutive addition of hours per week spent on various work activities	**High**	**Low**	**Diff**
21 or more hours: own research	76%	61%	+15%
36 or more hours: plus other professional productive work	63%	48%	+15%
41 or more hours: plus non-productive professional work	69%	48%	+21%
51 or more hours: plus other organisation activities	55%	48%	+7%
Base for each percent (i.e. number of cases)	(186)	(146)	
			Motivation to advance knowledge

(Glaser, 2008, p. 63). In light of data saturation, the researcher is encouraged to run the core index against all items in the data. To saturate categories of the emergent theory further, quantitative GT leverages at least three-variable cross-tabulations in another step. Thereto, two-variable relationships which have already been revealed are tested against at least a third variable. During this stage, the researcher is engaging in *theoretical ordering*. Theoretical ordering is based on emergence and means that items in the cross-tabulation provide potential relationships in direction. These relationships are utilised to refine or state new hypotheses. Generally, in quantitative GT (i.e. survey data analyses), the researcher is described to reach theoretical completeness within the limits of the available data set.

From *Level 2* to *Level 3* The final step is to integrate a multivariate theory with the pile of memos (i.e. in qualitative GT) or at least three-variable cross-tabulations (i.e. in quantitative GT) through sorting that guides the writing up of the theory as it is formulated. Generally, instructions for sorting activities are rather marginally described in the context of quantitative GT. In qualitative GT, sorting refers to a kind of granularity, meaning "that memos on the code and the code along with the data that indicated it can be scissored out of the memos and the field notes with ease for sorting" (Glaser, 1978, p. 42). Sorting is the last stage of a GT enterprise that demands the researcher's creativity, while the writing process is merely a write-up of sorted memos or cross-tabulations (termed *sorts*). Writing embodies the last empowerment in a research endeavour and conceptually occurs on the third and fourth (i.e. if desired) level. For sorting activities, qualitative GT does not prescribe any formalities and encourages

starting anywhere with any memo. Fundamentally, sorting implicates the emergence of a theory. At this stage of research, the researcher is largely looking for theoretical codes. This simultaneously assures a conceptual level to be maintained whilst writing. The objective is now to code theoretically, not substantially. In doing so, the researcher codes as many theoretical codes as possible. Theoretical codes structure and integrate the set of substantive codes. Coding families such as pictorial models are introduced to facilitate the writing process—in fact, every theory can be linearly drawn. These families allow the researcher to investigate and integrate the numerous possibilities found in the data. They are the schematic efforts to visualise conceptual relationships. It is generally advised to find a good concept-illustration dosage, while utilising theory illustrations without a corresponding text that yields the substance of connections should be avoided. The researcher is free to design what to present within the scope of the theoretical codes and the overall integration. Generally, the researcher should follow the rule of writing substantive codes while thinking in theoretical codes. In quantitative GT, the researcher is encouraged to take certain liberties in presenting the data as to, for instance, concentrate on the three-variable (or more) cross-tabulations to minimise the overall complexity (i.e. potentially hundreds of two-variable cross-tabulations).

During sorting and writing, the researcher starts to realise what literature is relevant for the substantive theory obtained, while theoretical completeness yields fruitful directions. Overall, the literature should be considered to corroborate the contribution to a substantive area. However, this task is not deemed mandatory as a generated theory provides novelty on its own.

Optionally: From *Level 3* to *Level 4* Every generated theory has generalisation implications. However, one may also wish to widen the scope of a substantive theory. This is achieved by either comparing the generated substantive theory to other substantive theories from the literature (as described in qualitative GT) or by including other survey studies (according to illustrations in quantitative GT). In doing so, the researcher strives towards creating formal theory, which Glaser (2006) covers more thoroughly elsewhere. However, transferability is achieved by the interchangeability of indicators.

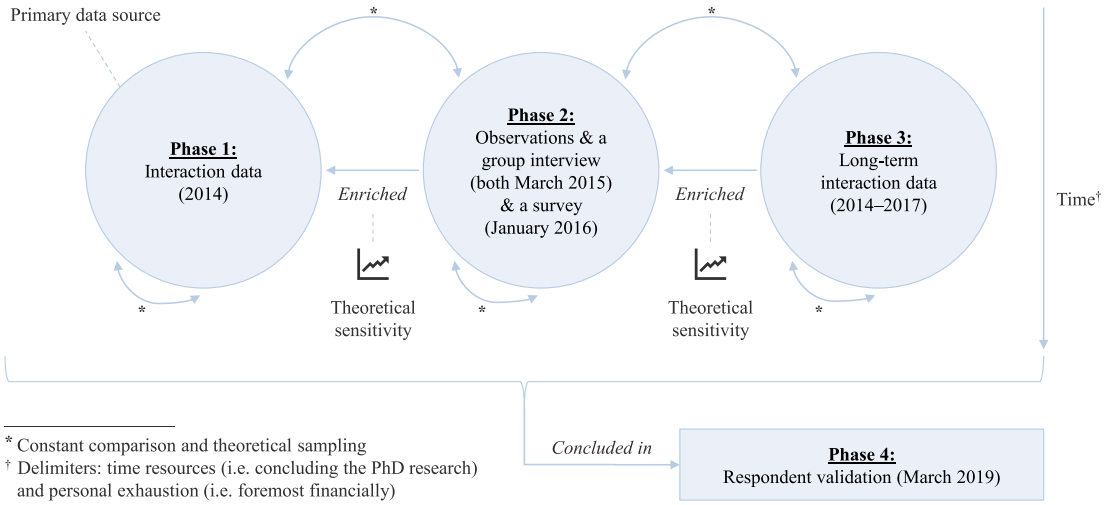

Figure 3.3: The four research phases and the different types of data utilised.

3.2.5.2 Practical Systematisation Approach

The research was initially confronted with little guidance in approaching analyses with a mixed-methods design in classic GT. Most notably, the instructions regarding quantitative data were of rather little assistance as this research intended to create its own stack of primary data. To systematise both data collection and analysis, this thesis builds on a constant comparison step-by-step approach introduced by Boeije (2002). She suggests that constant comparison does not entail comparing every piece of information throughout analyses, but to follow a sound plan. To this end, she presents four distinct criteria to be elaborated on throughout each step: firstly, the analysis activities (i.e. a description); secondly, the aim of comparisons; thirdly, the important questions asked; and lastly, the findings.

It shall now continue with the application of the first three of these four criteria. While this chapter solely concentrates on the general methodological underpinnings, Chapter 4 returns to the findings obtained by following the rationale described below.

Overview The data collection and analysis process organisation built on other GT studies that had organised their research in different phases (e.g. Hunter, 2014; Mathison, 2012; Walsh, 2015). This research happened to be organised in four different phases, accordingly labelled *Phase 1* to *Phase 4* (see Figure 3.3). This organisation illustrates the overall integration of both quantitative and qualitative data throughout

analyses. Every phase consisted of activities on all three levels of analysis in GT within the limits of its corresponding data, while it was aimed at incrementally increasing the maturity of the emergent theory with each phase. Therefore, corresponding pictorial models were utilised to conceptually and theoretically conclude each phase. These illustrations assisted in sorting substantive codes and in relating them to one another (i.e. theoretical codes). They further guided the process of writing up the theory as it was formulated in each phase.

Phase 1 only considered quantitative interaction data. Subsequently, a combination of both data sources in the form of observations, a group interview, and an online survey enriched the theory-generating process in *Phase 2*. *Phase 3* solely built on long-term quantitative interaction data. In both *Phase 1* and *Phase 2*, data was progressively being analysed. On the contrary, in *Phase 3*, statistical tests were retrospectively conducted and descriptive statistics were elaborated on. *Phase 4* concluded the theory-generating process by incorporating staff feedback stemming from a respondent validation to increase the authenticity of findings. Access information to all data sources can be found in Appendix B.1.

It was decided to create memos in this work. Among others, spreadsheet software was therefore utilised. Consequently, the memos were mostly digital artefacts in a variety of different formats such as diagrams, screenshots, and cross-tabulations. Occasionally, these memos were amended by further documentation such as handwritten notes and comments. For example, software bugs, change requests, and relevant correspondences were documented. A memo wall in the author's office space was utilised to collaboratively reflect on data and easily inspect and sort memos simultaneously (see Figure 3.4). In contrast to qualitative GT—where memos are a writing about ideas and the centre of analyses as well as quantitative GT, where they seemingly find no use—memos assisted greatly in reaching a level of abstraction to prompt new ideas (e.g. a substantive or theoretical code). Figure 3.5 exemplarily illustrates a crucial memo utilised during observations in *Phase 2*. In this depiction, a working day is split into 5-minute segments. For demonstration purposes, the actual observation presence times and absence times are highlighted. Besides provoking thoughts for new ideas, these artefacts assisted also in cross-referencing the findings from different research phases.

Figure 3.4: Parts of the memo wall utilised, displaying a diverse set of interaction data statistics, user interface screenshots, and diagrams in the author's office space.

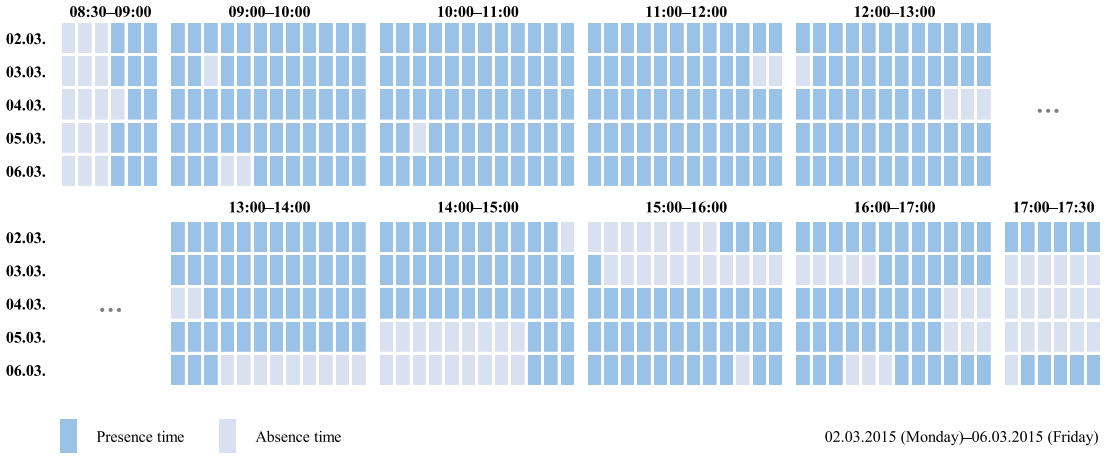

Figure 3.5: A crucial memo utilised in the constant comparison process through *Phase 2* presenting the author's presence (dark blue) and absence times (light blue) during observations in Week 10 of 2015.

***Phase 1*: Interaction Data** The research set out with guidance provided by Muller (2014), who generally encourages the researcher to choose methods which allow him or her best to perceive and know. It was decided to commence the research with sensor data stemming from the Ambient Surfaces' custom logging mechanism. This mechanism happened to be used as the primary data source in this research. Selecting a primary data source is also recommended in the literature (Stol, Ralph, and Fitzgerald, 2016). The motivation was fourfold:

1. No research questions were predefined. Interaction data arguably allowed a variety of usage patterns to be explored. Sensor data to track user activities is commonly utilised in ambient display research (Börner, Kalz, and Specht, 2013). Principally, logging is considered helpful in long-term research enterprises (Alt et al., 2012).

2. Phenomena such as the novelty effect and display blindness necessitated attention during analyses (Koch et al., 2018). It was initially anticipated that a novelty effect would be present to some extent. Interaction data arguably allows uncommon patterns in the material to be identified.

3. This method helped in keeping the initial resources in check. For instance, some studies report that they extended their research due to the prevalence of an initial novelty effect (e.g. Gallacher et al., 2015; Hazlewood, Stolterman, and Connelly, 2011). Data collection techniques such as observations would have arguably accounted for more time-intensive workloads (e.g. travel time). Workload-related concerns of observations are also highlighted by GT scholars such as Corbin and Strauss (2015).

4. As it is crucial in ambient display research to collect data unobtrusively (Börner, Kalz, and Specht, 2013), the logging mechanism arguably allowed data to be collected without distracting users.

Aim of Comparisons The primary aim of comparisons was to unveil somewhat saturated latent patterns—or what Glaser (1978, p. 40) refers to as "directing

hypotheses"—beyond the novelty effect and display blindness to guide future data collection activities. In doing so, emerging questions were documented as well as a stack of data created that could later be triangulated with other data sources. However, it was not necessarily intended to make a strong case on a conceptual level (i.e. *Level 2*) as it is described in quantitative GT with multiple variable cross-tabulation runs (e.g. consistency indices). Data was not scrutinised to identify the core category in this early stage of research. Overall, *Phase 1* was understood as an initial stepping stone towards the goal of generating theory.

Important Questions for Comparisons The following two fundamental questions were posed in advance for *Phase 1*:

1. During what times of the day is the Ambient Surface most prominently being utilised?

2. How long can the novelty effect be notably observed in the data collected?

Description of Comparison Activities In *Phase 1*, the idea of crude indices was leveraged and a crude index named *Utilisation of the Ambient Surface* was created. Again, to yield first grounded hypotheses, Glaser (2008) continuously compared items from a pre-defined set of survey data in terms of their directions in relations. In contrast, the present research compared the dimension (i.e. the value range) of one specific item over time in doing the same. Starting in February 2014, it was anticipated to sample data for at least a couple of months (e.g. due to the novelty effect). Analyses were scheduled to be conducted weekly. Log file downloads and analyses were scheduled at weekends, largely to avoid interfering with the use of the system during the daytime. It was expected that at some point, newly collected data would incrementally discontinue to indicate substantial differences. This issue became apparent at the end of 2014.

The logging mechanism stored interaction data in two separate files. The selected file here included information relating to *touch events*, which are events that were triggered in the software framework when a person interacted with the display's surface. For the sake of presentation, Listing 3.1 demonstrates content from the file that stored touch events. Each line in this log file stored information of different variables, namely

```
1 Timestamp of event                    Event type      Id      X       Y
2 2014-02-21 11:55:29.691 +01:00 ### Touch down ### 2 ### 970 ### 259
3 2014-02-21 11:55:29.698 +01:00 ### Touch move ### 2 ### 970 ### 259
4 2014-02-21 11:55:29.698 +01:00 ### Touch up   ### 2 ### 970 ### 259
```

Listing 3.1: A sample of touch events.

Timestamp of event (i.e. a unique timestamp of an event in milliseconds), *Event type* (i.e. values "Touch down", "Touch move", and "Touch up"), *Id* (i.e. a unique identifier for a single touch input produced by a finger and provided by the operating system), as well as an x-coordinate (i.e. values between 0 and 1,920) and a y-coordinate (i.e. values between 0 and 1,080). Analogously to Glaser (2008), every variable in this file potentially represented an item for the crude index. The most promising item, however, seemed to be *Timestamp of event* as it allowed usage to be described over time. The crude index contained two items: firstly, the item *Number of interactions*, which summed data from *Timestamp of event*; and secondly, the item *Times of day* that allowed *Number of interactions* to be organised in temporal segments. In doing so, this variable assisted in relating usage to specific times of day. It was then decided to split the working day into 27 half-hourly parts, while data was considered between 7 am to 8 pm in order to account for the majority of interactions. However, no dichotomisation of the index took place as, again, directions in relations were not sought after.

***Phase 2*: Observational, Interview, and Survey Data** Findings at the end of *Phase 1* progressively revealed that interaction data showed a certain degree of saturation. In a similar vein to Glaser and Strauss (1967) discussing the process of being pointed towards further data collection by the emergent theory, it felt necessary to collect additional data to enhance theoretical sensitivity. The theoretical purpose in mind was to increasingly conduct conceptual analyses (i.e. *Level 2*) as a further stepping stone towards a GT. While continuing to collect interaction data as the primary data source, it was then decided to enrich analyses with data stemming from observations, interviews, and surveys. The motivation was fivefold:

1. Contrary to interaction data, observations provided insights regarding passive usage by investigating people in their natural habitat. According to Corbin and Strauss (2015), observations place the researcher in the thick of the action.

2. Contrary to potential drawbacks of interviews, observations reveal what people are really doing and not what is claimed to be done. Observations are the only way to unveil such information (Corbin and Strauss, 2015).

3. In GT, interviews and observations only provide meaning when combined (Glaser, 1998). Interview data was intended to be used as a means of contextualising personal interpretations from observations.

4. Questionnaires are most effective when used in conjunction with other methods (Grix, 2010). Fundamentally, substantiating findings from earlier data collection activities was striven towards as this method was intended to be conducted after observations and interviews.

5. The findings of *Phase 1* were still rather descriptive in nature contrary to being explanatory for what was actually going on. It was aimed at a more comprehensive understanding by triangulating different data sources (Grix, 2010).

Aim of Comparisons The primary aim of the comparisons in *Phase 2* was to intensify analyses and expand the scope of the conceptualisation level (i.e. *Level 2*) by triangulating data stemming from different sources. In doing so, the earlier-stated directing hypotheses and some of the research questions from *Phase 1* were subjected to examination. It was also intended to pinpoint the core category. Glaser (1978) indicates that smaller studies (e.g. PhD theses) are required to selectively code as soon as possible given that available resources are limited. This step was issued during this stage of the research.

Important Question for Comparisons One crucial question was denoted in the context of *Phase 2*:

1. How is the emergent theory conceptually and theoretically enriched by triangulating it with observational, interview, and survey data?

Description of Comparison Activities Throughout *Phase 2*, open coding and selective coding practices were largely utilised. Here, analyses focused on identifying

indicators in the data to create categories and properties. Indicators were found in phrases, sentences, or whole paragraphs. Others refer to this approach as "key point coding" (Allan, 2003, p. 2). Data sampling aimed at discovering the core category. In the end, data from observations of a total of 1 week (i.e. 5 working days) was gathered and sequentially enriched by data stemming from a group interview as well as an online survey. This circumstance was built on the following considerations:

- It felt that a somewhat representative sample of data could be gathered during a week of observations that is sufficiently complementary to the primary data source. However, the questions of what constitutes a sufficient amount of observation time and of what time periods would be the most representative for all other weeks arose. For example, due to impacting factors such as the large number of employees in the same building (e.g. varying office presence times), it was a challenge to determine an adequate time horizon. Potentially, every single calendar week could likely have accounted for new findings.

- Similarly, it felt reasonable to assume that data stemming from one group interview and a subsequent survey would suffice in enriching the theory-generating process to a notable extent as these sources were also understood as complementary to the primary data source.

- Furthermore, the core category of *Spontaneous utilisation* conceptually emerged somewhat automatically throughout the group interview (Glaser, 1998). Furthermore, in combination with the sub-categories of *Information visibility* and *Passing-by*, all three categories seemed to account for the most parsimonious but simultaneously the greatest variation as regards the substantive behaviour (Glaser, 1998). While sorting and writing up the emergent theory, it became apparent that data was starting to get conceptually and theoretically saturated within the limits of the available data.

- Personal saturation, however, played a crucial delimiting part throughout this process. Generally, tasks such as making progress and conducting data collection as well as analysis activities were all time-consuming.

Table 3.2: Observation time periods during Week 10 of 2015.

Dates	Weekdays	Times of day	Presence time (in hours)	Observation time (in hours)
02.03.	Monday	08:45–17:30	8.75	8.00
03.03.	Tuesday	08:45–17:00	8.25	6.58
04.03.	Wednesday	08:45–16:45	8.00	7.50
05.03.	Thursday	08:45–16:45	8.00	7.17
06.03.	Friday	08:40–17:30	8.83	6.67
		Total:	**41.83**	**35.92**

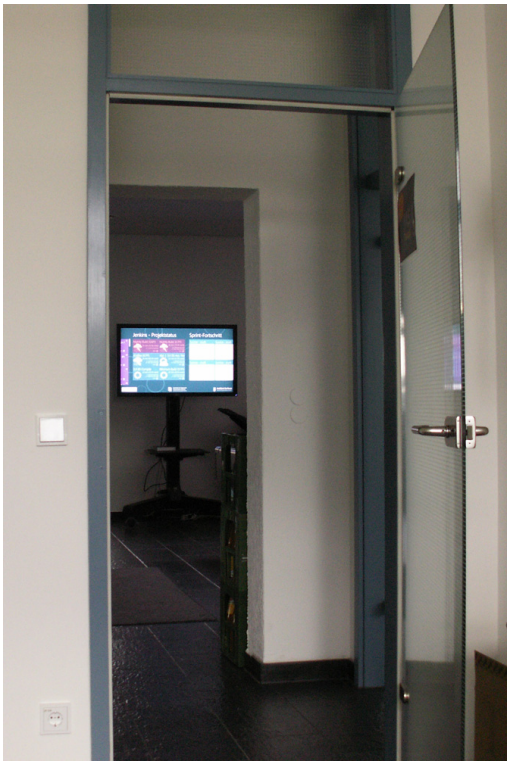

Figure 3.6: The observation setup in March 2015 and its field of view towards the first Ambient Surface.

Observations commenced on Monday the 2nd March of 2015 and lasted for the entire week. Table 3.2 provides details from this time period. Both the presence time and the observation hours varied due to events such as ad-hoc discussions with staff members. Observations were non-participant in nature (Grix, 2010). They were also not announced in advance other than in communication with contact persons who helped throughout the organisational process. Thus, the majority of the staff were kept unaware of the observations to allow their actual authentic usage to be captured. Figure 3.6 illustrates the view of the observation setup. An entire office was available

for the time of observation and provided a direct view towards the Ambient Surface. Due to the office's location, this setup allowed the observer to be in the surrounding environment mostly unnoticed. However, it was only possible to observe people from behind.

The decision whether to conduct individual interviews or a group interview was left to the project partner. In the end, the company organised for a group of representatives to participate in a group interview. The interview was conducted on Friday the 6th of March 2015 between 1:30 pm and 2:30 pm. It could be characterised as semi-structured (Grix, 2010) as questions (see Appendix B.3.1) were prepared in advance but were not intended to be answered in a defined order. The circa 54-minute interview was subsequently transcribed[3]. Six people participated while one interviewee had to leave the interview for approximately 20 minutes for another appointment. The interview was joined by two Scrum Masters, three software developers (each from a different software development team), and one head of department.

The online survey followed roughly nine months later and people were able to participate between the 7th of December 2015 and the 7th of January 2016. The reason for this time gap was threefold: firstly, analyses of observational and group interview data took a notable amount of time; secondly, reasonable efforts were spent on revising the Ambient Surface in collaboration with the project partner, foremost regarding the requested installation of a second screen in August 2015; and thirdly, preparing and pretesting the questionnaire were time-consuming work packages. From a total of 76 invited employees, 35 people successfully completed the questionnaire (i.e. circa 46%). In the online survey, different types of questions (see Appendix B.3.2) were utilised (e.g. 6-point Likert scale and open-ended). Generally, the questionnaire can be characterised as self-administered and internet-mediated (Saunders, Lewis, and Thornhill, 2009) as people completed the questionnaire on their own using an online survey tool operated by the HAW Hamburg.

Fundamentally, comparisons that enriched ideas from *Phase 1* were sought after. To this end, observation field notes, the transcript of the group interview, and the survey

[3]To this end, the work from Flick (2009) was consulted (see Appendix B.2).

results were the basis for this task. Field notes were digitally documented and analysed using word-processing software. They contained a tabular structure that was organised in hourly segments. In that way, specific incidents could be related to certain times of day. Events such as people passing by, people stopping in front of, or people interacting with the system were documented. For analyses relating to the group interview and the online survey, *MAXQDA*[4] was leveraged to create codes. Overall, the following comparisons were conducted in *Phase 2* and felt like an adequate supplement to the gathered interaction data:

- Compare observed *noise levels*[5] in the building throughout the day to reveal potential correlations between active and passive usage with specific incidents.
- Compare observed times of day with respect to the total number of passers-by to indicate explanations for the varying latent patterns found in *Phase 1*. The idea to collect and compare these numbers emerged through the observation process itself on the third day.
- Compare observed instances of active and passive usage to find out more about how the system was actually being utilised.
- Cross-compare findings from *Phase 1* with findings from observations.
- Compare interviewees' feedback from the group interview.
- Cross-compare findings from *Phase 1*, observations, and the group interview.
- Cross-compare findings from *Phase 1*, observations, the group interview, and the online survey.

***Phase 3*: Long-term Interaction Data** *Phase 3* marked the final stepping stone towards investigating the Ambient Surfaces' long-term usage. Generally, *Phase 3* embodied a response to the issue that analyses continually progress as the researcher

[4] https://www.maxqda.com/

[5] Noise levels refer to the following: it felt relevant to learn more about times of day in which people were moving more throughout the building, were talking more to each other, and—in contrast—when people were apparently concentrating more on their work.

becomes immersed in data. At some point, the researcher has to stop analysing data (Corbin and Strauss, 2015). It was a compromise of weighing up the pros (e.g. gaining insights through new interchangeable indicators) and cons (e.g. restricted time constraints and personal exhaustion) of collecting further material. The reasons for incorporating long-term interaction data were twofold:

1. Previous analyses mostly elaborated on when utilisations occurred. *Phase 3* enriched analyses with respect to what content people were actually utilising while interacting with the screens over the course of several years.

2. Furthermore, both preceding phases failed to consider statistical investigations of long-term interaction data to, for instance, pinpoint conditions that may underlie prevalent latent patterns.

Aim of Comparisons The primary aim of *Phase 3* was to further saturate the conceptual and theoretical underpinnings of the emergent theory. It was aimed at concluding the generation process of a modifiable substantive theory. Fundamentally, it was targeted at achieving theoretical completeness within the limits of the available data meaning that it seemed all data considered from the three research phases conceptually fit.

Important Question for Comparisons Similarly to *Phase 2*, there was one analogously important question targeted in this stage of the research:

1. How is the emergent theory conceptually and theoretically enriched by triangulating it with quantitative long-term interaction data?

Description of Comparison Activities During analyses, both spreadsheet software and *SPSS*[6] were utilised to investigate the data. Again, *Phase 3* attempted to retrospectively scrutinise long-term interaction data (i.e. 2014 to 2017). The goal was not to direct theoretical sampling to further data sources. Contrary to *Phase 1*, *Phase 3* also leveraged the second file that stored interaction data and additionally

[6] https://www.ibm.com/analytics/spss-statistics-software

```
1 Timestamp of event                    View          Activity
2 2014-02-24 13:03:35.556 +01:00  ###  Jenkins  ###  Opening a project
3 2014-02-24 13:03:37.591 +01:00  ###  Jenkins  ###  Scrolling the jobs list
4 2014-02-24 13:03:37.620 +01:00  ###  Jenkins  ###  Closing a project
```

Listing 3.2: A sample of view events.

focused on what is referred to as *view events*. View events considered a multitude of custom events such as scrolling gestures. Listing 3.2 shows a simplified example of data from the second file containing these events relating to the utilisation of the software. Similarly, each line in this file correspondingly stored information. Besides the variable *Timestamp of event*, there were, for instance, the variables *View* and *Activity*. Generally, the file stored activities such as opening and closing information views, navigating through content, and submitting a form. This file enabled actual interaction behaviour with specific content to be analysed.

Phase 3 leveraged two cross-tabulations relating to view events. Firstly, it was intended to find the most utilised information views with respect to *Times of day* according to *Number of interactions*. Secondly, a further comparison focused on percentage figures that related view events to both years and systems to infer initial conclusions on the relevance of content. Furthermore, statistical analyses on the basis of touch events were conducted. Interaction data stemming from similar conditions was intended to be compared statistically. Finally, the findings of *Phase 3* were considered in a cross-comparison with the results of the previous research phases.

***Phase 4*: Respondent Validation** As a concluding stepping stone for this research, it was decided to conduct a respondent validation. A respondent validation—or member check—is most crucial in achieving credibility (Lincoln and Guba, 1985). It is considered an element of triangulation and embodies an important corrective to the overall research (Torrance, 2012). The method was leveraged during the data checking stage (i.e. contrary to considering it in the context of preliminary findings)—that is, attendees were asked whether findings were "a fair and reasonable reflection of the situation as they understand it" (Torrance, 2012, p. 114).

The respondent validation was conducted on the 1st of March 2019 and organised as a group session, including a presentation and a subsequent interview. The group

interview can be characterised as unstructured as no predefined set of questions was prepared (Saunders, Lewis, and Thornhill, 2009). The nine attending staff members were: four Scrum Masters, one head of department, one computer science student, and three software developers. Two Scrum Masters and the head of department already participated in the group interview conducted in *Phase 2*. Additionally, both PhD supervisors from the HAW Hamburg attended the meeting. The organisation was as follows: firstly, the author initially held a presentation and discussed foremost pictorial models stemming from *Phase 3*; secondly, participants were asked to provide feedback on these illustrations. This second part was audio-recorded. The audio file, lasting roughly 43 minutes, was also subsequently transcribed and analysed in MAXQDA.

Aim of Comparisons The main purpose of the comparisons in this final stage was to evaluate how employees contradicted or concurred with illustrations of the generated substantive theory.

Important Question for Comparisons Consequently, the following question was targeted in *Phase 4*:

1. How do attendees contradict or concur with the pictorial depictions of the proposed theory in *Phase 3*?

Description of Comparison Activities Similarly to coding activities conducted in *Phase 2*, the group session transcript was open-coded in MAXQDA. However, coding was done with a selective lens as it was primarily concentrated on how newly gathered indicators revised the existing theory of *Phase 3*. At this point in time, analyses came to an end. In cross-comparing all research phases, the author performed the final round of sorting and writing up in the form of a concluding pictorial depiction. No further sampling of data was conducted.

3.3 Research Setting

This section introduces the company which partook in this research. Therefore, the following initially describes the origins of this collaboration briefly (see Section 3.3.1).

The company is then subsequently presented (see Section 3.3.2). After that, it is concentrated on the participating software development department (i.e. the study population, see Section 3.3.3) and the adopted software development process (see Section 3.3.4).

3.3.1 Selection Procedure

The research setting was readily available when the present study commenced. The collaboration with *Werum IT Solutions GmbH*[7] (hereafter referred to as *Werum*) originated from their participation in a workshop in August 2013 at the HAW Hamburg. In this workshop, the concept of the Ambient Surfaces solution was presented to an audience of around 15 industry representatives. Two Werum employees partook in this event. Principally, Werum was interested in addressing issues surrounding inter-team coordination and information awareness. After the presentation, the company showed strong interest in the given topic and follow-up appointments were subsequently scheduled at their headquarters to introduce the topic to a broader audience, to discuss concerns, and to initiate the next steps. This process finally resulted in the deployment of a first system in February 2014.

3.3.2 The Company

Werum was founded in 1969 and its headquarters is in Lunenburg, Germany. In 2014, it was acquired by the non-profit Körber Group and was divided into two smaller companies. At the time of the acquirement, Werum was largely owned by its own staff. The company operates different offices worldwide, including in Asia, America, and Europe. As of 2019, Werum employs roughly 600 people across the globe. Most of the staff are located at the company's headquarters (circa 430 people). All other employees are distributed across the globe. About 80% of the employees hold a degree in higher education (of those, 94% with a background in the disciplines of science, technology, engineering, or mathematics) and 20% completed apprenticeships in technical (12%) as well as business-related (8%) professions. The company specialises in developing

[7] https://www.werum.com/en/home/

manufacturing execution systems and IT solutions for the pharmaceutical and biopharmaceutical industries and is simultaneously the world's leading supplier for such solutions. Werum's custom product is utilised by the world's top 30 pharmaceutical and biopharmaceutical companies as well as by mid-sized manufacturers.

3.3.3 Study Population

Werum's software development department participated in the present research. The overall population, including its changing number of agile teams throughout the present study (i.e. four to eight in total), can be denoted as a large-scale ASD environment (Dingsøyr, Fægri, and Itkonen, 2014). Roughly 70 to 80 people were employed in this department. Based on the online survey (n = 35), the staff can be characterised as follows: almost 90% of employees were older than 30 years old while the majority (48.6%) ranged between 31 to 40 years of age. Circa 80% of the staff were male. The majority of employees in this department were software developers (62.9%), followed by Scrum Masters and Product Owners (both 14.3%), team leaders, heads of department, administrators, and others (each 8.6%). Over one-third of staff members had been working at Werum for 11 to 20 years (34.3%), followed by 22.9% of respondents who had been employed for between 3 and 5 years. Almost 90% (n = 34) of the staff had graduated with either a bachelor's (11.8%), a master's (11.8%), or diploma degree (64.7%) from universities or other academic institutions. Here, an emphasis in education on computer science and related majors was notable.

3.3.4 Software Development Process

Approximately one year prior to the research project (i.e. in November and December 2012), Werum initiated a transition to *Scrum* (Schwaber and Beedle, 2001). Prior to this transition, the company had been using the *waterfall software development model* (Royce, 1987) and faced different challenges during the process of developing software. For instance, issues were a lack of scalability, inaccurate estimations of user stories, insufficient planning, overtime work, interruptions of software developers, a lack of knowledge distribution among software developers, and software quality. In contrast, Scrum reportedly provides a fixed framework for developing software, which

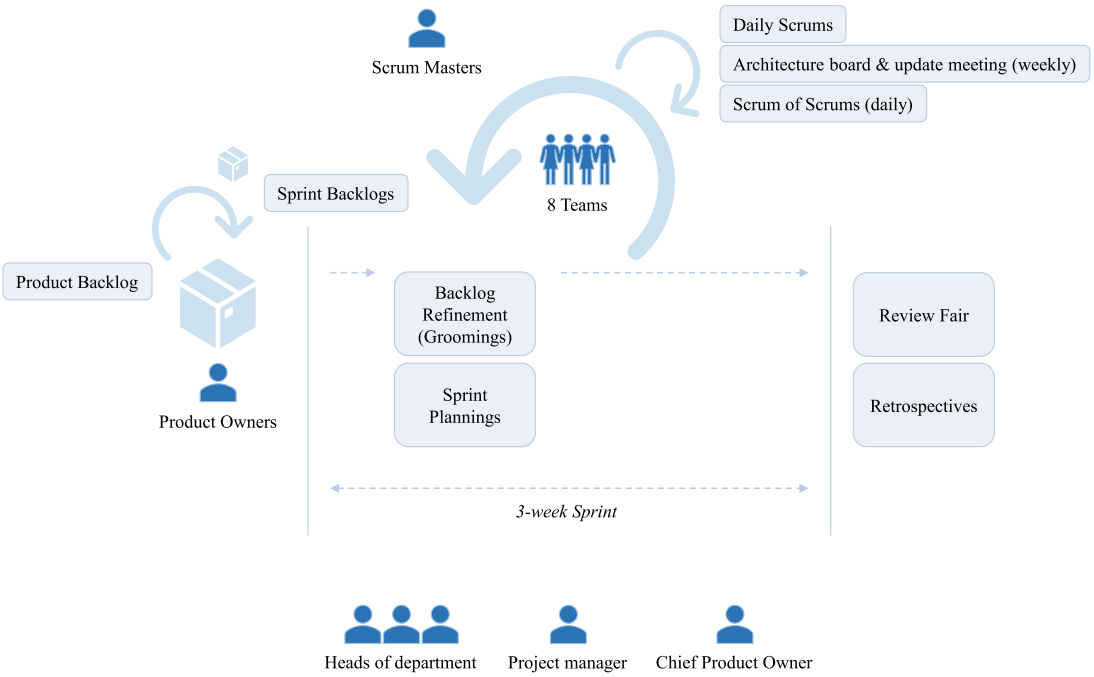

Figure 3.7: The Scrum process adopted and utilised by Werum, including all relevant personnel and meetings.

was perceived as an advantage of this method. It also supposedly allows the idea of inspection and adaption to be incorporated. In January 2013, the first agile Sprint with one Scrum team was initiated hence the Scrum maturity level at the beginning of the study went beyond the adoption level. While Werum's Scrum implementation constitutes the fundament of the software development process, it is also enriched by practices from further agile methods such as *Extreme Programming* (Beck, 1999) and *Kanban* (Anderson, 2010) in the case of software maintenance.

The overall Scrum process adopted is depicted in Figure 3.7, including all relevant roles, teams, and meeting practices[8]. Generally, such custom adoptions (cf. Schwaber and Sutherland, 2017) are typically seen in the industry (Diebold et al., 2015). However, some personnel such as architects are not denoted in this figure as they are recruited from individual teams. Also, collaborating teams that are external to the software development department were excluded from this illustration. A Sprint is typically conducted in a 3-week cycle (except, for instance, around New Year) as Werum exper-

[8]The Daily Scrum (11:45–12:00) and Scrum of Scrums meetings (11:30–11:45) were the only meetings that were repeatedly held at the indicated time slots throughout the entire study, while the conduct of the other meetings varied to a lesser (e.g. the weekly update meeting was typically conducted between 11:00 and 11:30) or greater extent (e.g. the individual team Sprint Planning meetings).

ienced it to best fit their requirements (e.g. 2-week Sprint cycles were insufficient in providing enough time for software development progresses aside from tasks such as regularly attending meetings). Normally, a Sprint starts on a Monday and ends on a Friday.

The product-based focus is reflected in the company's software development process. For example, teams develop and maintain the custom product with no constraints such as varying technology stacks or context switching. They typically deploy product increments after each Sprint. To this end, staff members are equipped with a variety of tools that assist them in developing the company's software product. For the context of this thesis, the following tools deserve a special mention:

- *Atlassian Jira*[9]: Jira is utilised to, for instance, create and maintain user stories, plan Sprints, coordinate the teams, and ascertain the traceability between functional requirements and code changes.
- *Atlassian Confluence*[10]: Confluence is most notably used for knowledge sharing purposes such as architectural decisions and coding guidelines. Another huge part is documentation. For example, the company protocols every Sprint in Confluence (e.g. attendees).
- *Jenkins*[11]: Jenkins was used for continuous integration purposes. For example, different build jobs such as nightly builds (mandatory for a product release and triggered every night) and continuous builds (for developing purposes and scheduled every half an hour) were leveraged.
- *GoCD*[12]: GoCD replaced Jenkins in 2017 and is used to automate the build and deployment infrastructure to automatically deliver software product increments.
- *Tetris* (custom): The idea behind this tool is threefold: firstly, to illustrate what tests were conducted; secondly, to show whether their execution was successful or not; and lastly, to indicate who is responsible for fixing tests in case of

[9] https://www.atlassian.com/software/jira
[10] https://www.atlassian.com/software/confluence
[11] https://jenkins.io/
[12] https://www.gocd.org/

failures. While in 2015 a simple custom website was run to display such information, the department incrementally developed this more sophisticated tool as a replacement. Tetris builds strongly on the available automated test suite and dynamically gathers information during test runtime.

- *Avatar* (custom): The Avatar tool originates from a bachelor dissertation that was conducted in the department. As with Tetris, this tool is also based on the available automated test suite infrastructure. With the help of static source code analyses, the website illustrates test metrics (i.e. mostly charts) referring to general test availability and how tests relate to architectural requirements.

3.4 Custom Ambient Display Solution

This section introduces the custom ambient display solution utilised throughout this study. Therefore, its foundations in the form of the software development framework and its architecture are outlined in Section 3.4.1. Subsequently, the hardware components are presented (see Section 3.4.2). It is then continued with an illustration of the varying information views and features in Section 3.4.3 and finally, an evolutionary overview of the solution is illustrated (see Section 3.4.4).

3.4.1 Software Application Outline

The first crucial component is the custom software application itself. It was responsible for handling touch interactions with the displays, selecting data from the aforesaid tools, and preparing the corresponding visualisations. The software built on the *Microsoft .NET framework*[13], particularly on its graphical subsystem *Windows Presentation Foundation*[14] to render user interfaces. This software suite was utilised in this work as the author already had experience with it from previous studies prior to the PhD programme (see Section 2.3.1).

[13] https://docs.microsoft.com/en-us/dotnet/
[14] https://docs.microsoft.com/en-us/dotnet/framework/wpf/

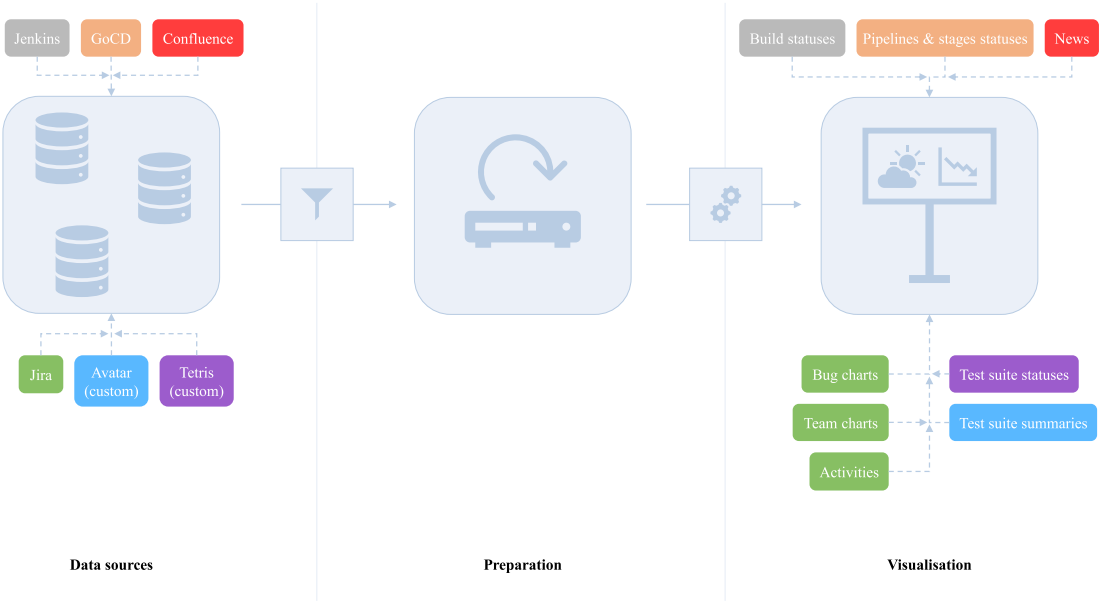

Figure 3.8: A simplified illustration of the Ambient Surfaces' software architecture, visualising the tools, and the content used during the field deployment.

Figure 3.8 illustrates the simplified architectural outline of the software application, while the matching colours indicate relationships of data sources and corresponding visualisations. Fundamentally, the development was inspired by related work in the domain of large display research (e.g. Churchill et al., 2003; Koch, 2005; Koch and Ott, 2011; Russell and Gossweiler, 2001; Snowdon and Grasso, 2002). For instance, according to Snowdon and Grasso (2002), the software application was initially configured to schedule an update job every 10 minutes to refresh visible information. Also—as indicated by Churchill et al. (2003)—the software was configured to automatically scroll through its content after 60 seconds of inactivity.

The architecture consisted of three logical parts: varying data sources, a preparation stage, and finally, a visualisation component. Data sources were included in two distinct ways: firstly, data was collected via the various APIs that were provided by these tools and secondly, data sources were included as is (e.g. a Wiki website). Depending on the degree of customisations, data sources required preparations to varying extents. While content such as websites and team charts were not visually revised, other data sources required more preparation (e.g. Jenkins).

Figure 3.9: The two Ambient Surfaces in their latest installation location (the photo was taken in 2017). During 2018, a table football setup was also placed left to the systems and both systems were slightly moved to the right.

3.4.2 Hardware Components

A description of all relevant hardware components shall follow. This includes the displays, touch sensors, and the different computers. Since the software application was operated solely using touch gestures, no keyboards or mice were part of the Ambient Surfaces installations.

3.4.2.1 Displays and Touch Sensors

In total, three different displays from varying vendors were utilised throughout the study. All displays were mounted on a rack with rolling wheels in a landscape configuration (see Figure 3.9). The total height of each installation was roughly 1.80 metres. All monitors provided a 1080p resolution (i.e. 1,920 × 1,080 pixels) and infrared touch sensors allowing the simultaneous detection of between 2 and 32 touches respectively. The displays' touch sensors were connected via USB cables.

The first device utilised was a 46-inch *NEC P461* monitor, which had already been used in past field deployments (see Section 2.3.1) and was complemented by a touch

sensor called *dreaMTouch*[15]. This sensor utilised an infrared frame which was installed on top of the screen's surface and allowed up to 32 simultaneous contact points to be detected. Due to a sensor failure, this display was replaced in 2016 by a 46-inch *Iiyama ProLite TH4664MIS-B2AG* monitor. In terms of touch sensors, this monitor also incorporated an additional infrared frame and could detect up to 10 contact points at the same time. In August 2015, a 47-inch *LG M4716T* monitor was deployed to operate a second system. This monitor also used an infrared frame configuration and supported up to two simultaneous contact points.

3.4.2.2 Computers

Two computers were utilised to operate the displays and to run the software application. Both machines had no internet access and were only able to connect to selected local resources in the company's intranet. Typically, these connections were set up in cooperation with the operations department. The first machine was a Mac mini from Apple with the model number *MC438LL/A*. This model is the server variant without any optical drive. The second computer was a *Fujitsu Esprimo Q910*, also a small form-factor machine that included an additional optical drive. More details regarding the hardware components of these devices are provided in Appendix C.1 and C.2.

3.4.2.3 Installation Setups

There were two distinct locations in which both Ambient Surfaces were situated. Both buildings provided room for roughly 70 to 80 people (i.e. the software development staff). Figure 3.10 and Figure 3.11 correspondingly illustrate a depiction of these locations. Between the 21st of February 2014 and the 15th of February 2017, both systems were placed in the location referred to in Figure 3.10. However, in Week 6 of 2017, all employees from this building were relocated to a newly constructed building. Both Ambient Surfaces were transferred a week later and were initially placed in a temporary location. Finally, on the 15th of March 2017, both systems were relocated to their new and final location (see Figure 3.11).

[15] http://www.citron.de/index.php?id=187

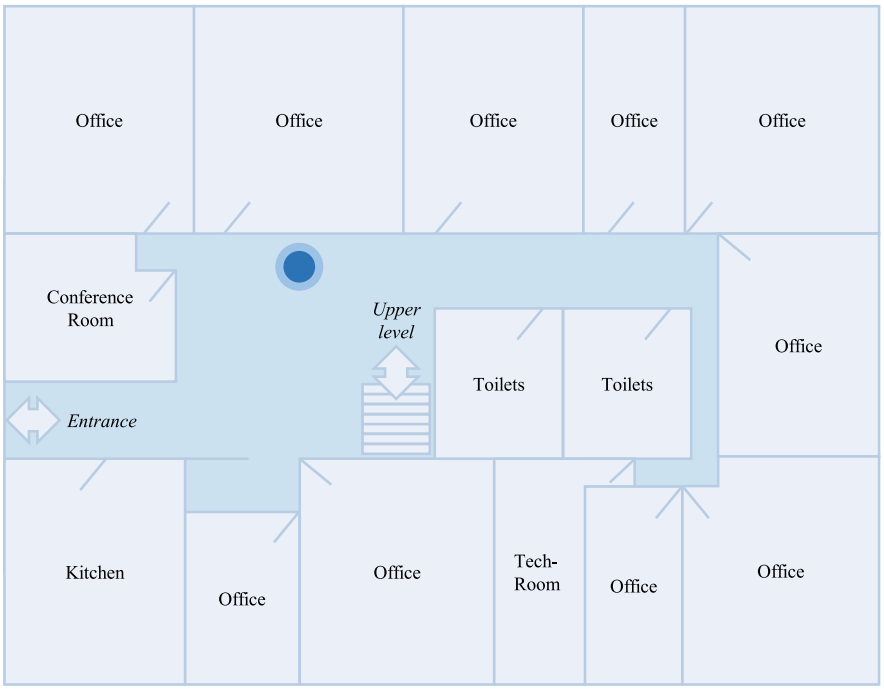

Figure 3.10: A floor plan of the old two-storey building's ground level, illustrating the first setup between February 2014 and February 2017. The blue dot indicates the location of both Ambient Surfaces at that time.

Both locations showed a large number of passers-by, while study participants reported that the total number of passers-by felt lower in the second installation setup. In the first location, people had to walk past the Ambient Surfaces, for instance, when arriving at or leaving work as well as when taking some food or a beverage from the kitchen. Similarly, in the second location, people had to pass by the systems, for example, when having lunch in the new canteen or using the toilets. However, this location provided multiple entrance areas hence people did not necessarily have to walk past the systems. Additionally, in the old building, there was a printing machine, a pool table, a stairway to the second floor, and beverages located in the same area. Correspondingly, beverages, cork boards, tables, and chairs, as well as a table football setup were placed in the surrounding area in the new building.

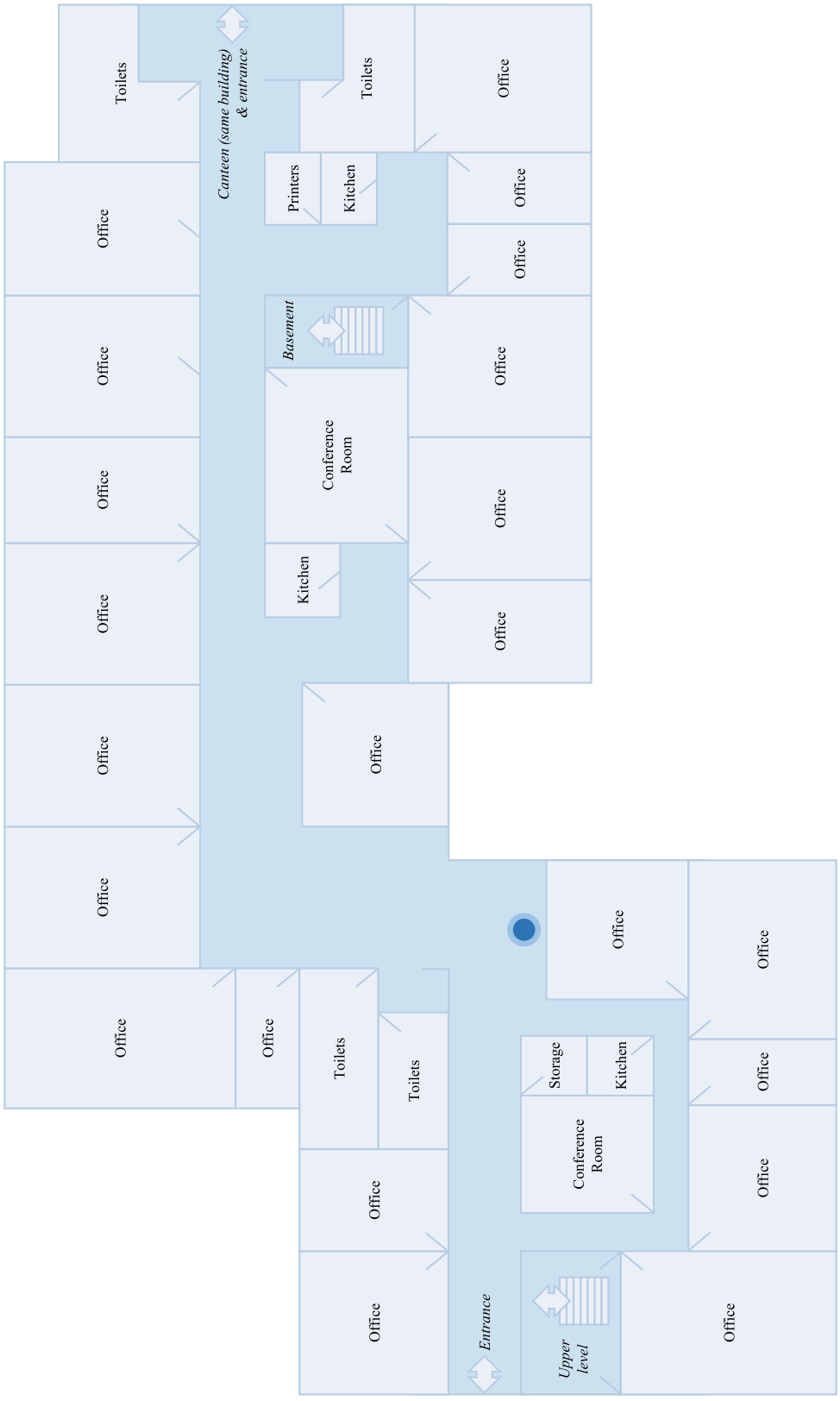

Figure 3.11: A floor plan of the new two-storey building's ground level, illustrating the second setup since March 2017. The blue dot indicates the location of both Ambient Surfaces.

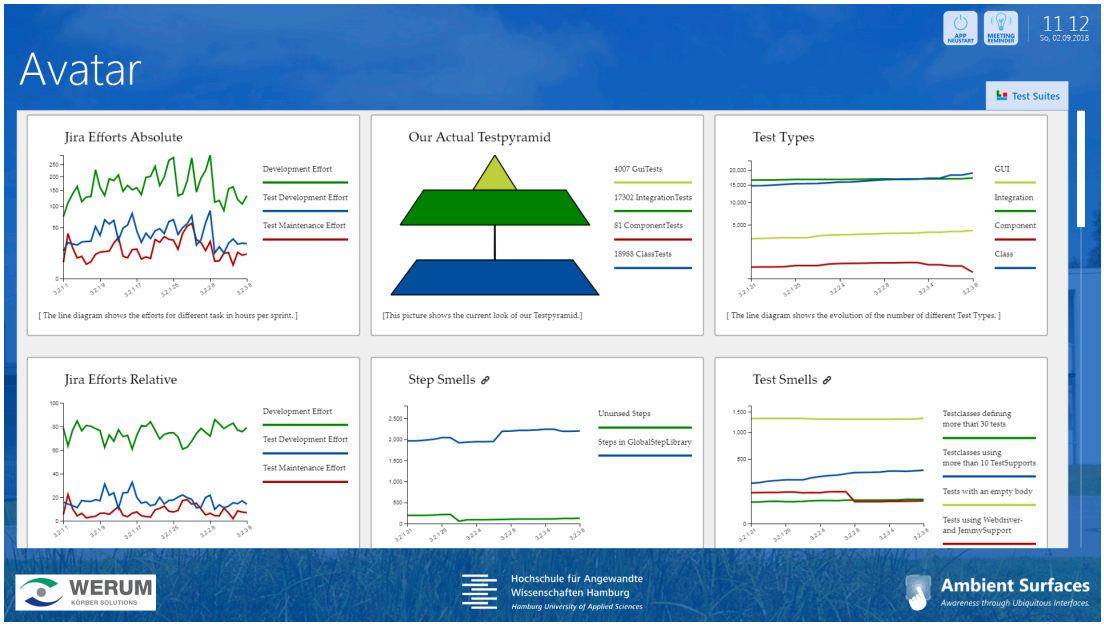

Figure 3.12: The *Avatar* view as of 2018. The clock in the right upper corner was configured to display abbreviations of weekdays in German (i.e. "So" corresponds to Sunday). The German label in button "App Neustart" refers to the process of restarting the software application (i.e. analogously "App Restart").

3.4.3 Information Views and Features

Eight information views and two distinct features were utilised throughout the study. These included the views labelled *Jira* (i.e. activities), *Jenkins* (i.e. build statuses), *Team Charts* (i.e. team charts), *Confluence* (i.e. news), *Test Suites* (i.e. test suite statuses), *GoCD* (i.e. pipelines and stages statuses), *Bug Survey* (i.e. bug charts), and *Avatar* (i.e. test suite summaries), as well as the features *Meeting Reminder* and *Sharing*. An example is provided in Figure 3.12 that illustrates the *Avatar* view. Screenshots and brief descriptions of the other views and features are provided in Appendix C.3. The *Avatar* view was the most recent view, which was added in Week 9 of 2018. It primarily displayed line charts (e.g. test types) which were incorporated as a static screenshot. The software application was configured to display either two views at a time (i.e. each half of the display's width) or one view on its own, depending on the data being presented. The top of the displays was occasionally utilised by the author to make announcements in a small coloured box (e.g. updates). The bottom of the screens presented Werum's company logo, the University logo, and the Ambient Surfaces logo. At the right upper corner, the *Meeting Reminder* feature was integrated and allowed to notify colleagues via an email function to remind them of a meeting.

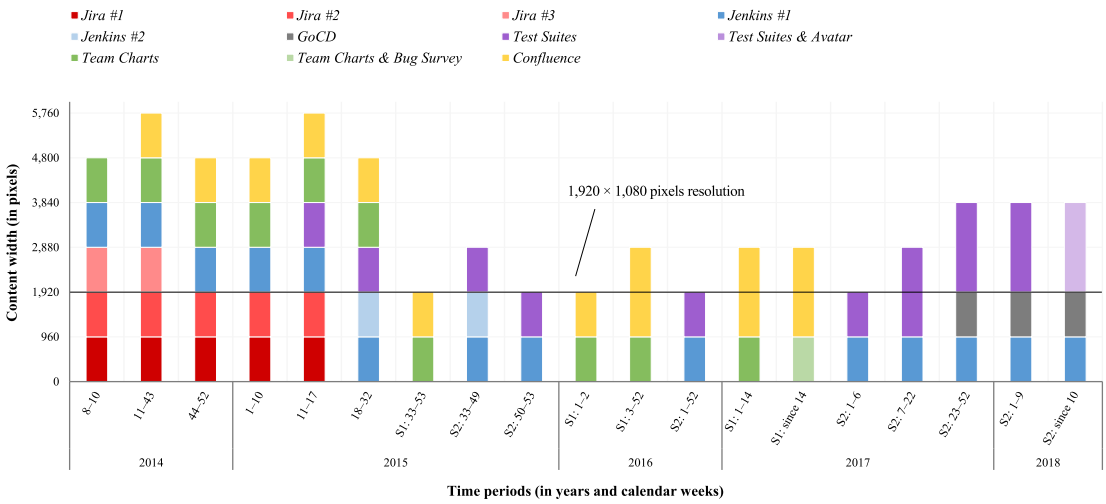

Figure 3.13: The evolution of both Ambient Surfaces (labelled *S1* and *S2*). Here, content widths resulting from adding, removing, and resizing information views are related to particular time periods.

Fundamentally, the views utilised different means to present data, whereas some were entirely custom-made. The views *Jira*, *Jenkins*, *Team Charts* (i.e. prior to its revision), and *GoCD* provided a certain number of information layers. These layers were nested user interfaces that presented varying extents of information. The general idea was to increase the level of detail as people navigated into these nested layers. While the views *Jira*, *Team Charts*, and *GoCD* used two layers, the *Jenkins* view incorporated four different layers. Furthermore, these views offered an additional user interface (i.e. the feature *Sharing*) to share selected information with colleagues via email (accessible via a button in the corresponding second layers and below). Also, the views *Jira*, *Jenkins*, and *Team Charts* provided a QR code that allowed employees to capture the information of interest with a mobile device. The other views—namely *Confluence*, *Test Suites*, *Bug Survey*, and *Avatar*—provided no such nested layers as they presented data as is from different intranet sources.

3.4.4 Chronology of Information Views

Principally, the evolution of both systems was a result of change requests from Werum (e.g. obsolete information) hence the information displayed varied over the course of the study. To provide an abstract chronological overview of this evolution, Figure 3.13 illustrates a bar chart diagram displaying information views (coloured elements) relating to time periods (x-axis) and the space they occupied on the screens in pixels (y-axis).

The organisation in different time periods is a result of adding, removing, and resizing (i.e. increasing the width) information views. Other minor activities (e.g. redesigning parts of an information view) are not included in this illustration as it was focused on conveying an initial glance at this issue.

Figure 3.13 organises the different information views as they were incorporated into the software application. For instance, in 2014 it was set out with five initial information views (i.e. including three instances of the *Jira* view). These views added up to a total of 4,800 pixels in width, while the three *Jira* views accounted for the first 2,880 pixels (960 pixels each). Following the *Jira* views, the views *Jenkins* and *Team Charts* were each embedded with 960 pixels in width. Given that all displays supported a maximum of 1,920 pixels in width, users were required to scroll horizontally through the content. Consequently, users had to utilise scrolling gestures more frequently prior to the installation of a second display in Week 33 of 2015. Subsequently, the information views were distributed across the two available screens. Information views typically also required users to leverage vertical scrolling gestures due to the size of the content. Some views also shared the same space on the screens (i.e. the views *Test Suites* and *Avatar* as well as the views *Team Charts* and *Bug Survey*). Accordingly, these views were jointly incorporated into the user interface. Overall, considering the time span of 2014 to 2018, the last major revision for one system was deployed in 2017 (i.e. *S1*) and for the second one in 2018 (i.e. *S2*).

3.5 The Role of the Researcher

The author was neither engaged in a professional relationship with Werum nor was he paid for tasks such as maintenance work (e.g. bug-fixing and updating information views). All issues were addressed in the author's free-time, mostly at the weekend or at night to reduce the offline times during a working day. Werum equipped the author with a notebook to access and maintain both systems via a remote connection. Throughout the entire study, the author was largely in contact with Scrum Masters who assisted in tasks such as scheduling data collection activities (e.g. the group interview) or answering specific questions regarding Werum. Vice versa, these Scrum Masters typically

contacted the author in case any issues occurred with the systems. Communication was mostly conducted via email, but also by telephone in some instances. Occasionally, the author also travelled to clarify issues further on site.

3.6 Ethical Considerations

Addressing potential ethical issues is a key concern for researchers (Ross, 2016). To varying extents, this work notably incorporates data based on feedback and the behaviour of human beings. Consequently, ethical considerations were an important part of this work, including an informed consent (see Section 3.6.1), steps to maintain confidentiality and anonymity (see Section 3.6.2), as well as activities to assure the security of the data (see Section 3.6.3). Such considerations stand in light of the September 2016 *Guidelines for Ethical Practice in Research and Scholarship*[16] released by the UWS Ethics Committee.

3.6.1 Approval and Informed Consent

Ethics approval for this research was granted by the University's ethics committee in March 2017 (see Appendix D.1). Werum—represented by an employee who oversaw the project—gave their informed consent in May 2019 (see Appendix D.2). This consent included, for instance, that Werum agreed to the disclosure of the company's full name in this work, scientific publications, and less rigorous formats.

3.6.2 Confidentiality and Anonymity

Several steps were taken to ensure confidentiality and anonymity. Confidentiality is maintained in such a way that all identifying characteristics of individuals were either removed from the final documentation due to irrelevancy (e.g. hair colour) or replaced by a synonym, such as in the case of names (e.g. *Mr Pink*). This issue mainly concerned the group interview, observations, and the respondent validation, while identifying information is only retrievable by the author. It is noted, however, that due to the

[16] https://www.uws.ac.uk/about-uws/uws-commitments/university-ethics/

small number of participants, such as in the group interview (i.e. six employees), it is possible that in reading the present thesis, employees may recognise passages that were said by other colleagues.

Issues surrounding anonymity were primarily a concern in one instance. Online survey respondents were asked to provide some basic information such as gender, age, and role. To maintain anonymity, the online survey tool *EvaSys*[17] hosted by the HAW Hamburg was chosen to administer the survey. The author sent invitations to respondents via this tool. Completed questionnaires were processed internally by this software and auto-generated reports were downloaded from the tool's website. In doing so, respondents were kept anonymous to the author—which was also the case for users in terms of interaction data.

3.6.3 Storage and Security of Data

For all research activities, one desktop computer and one laptop computer were used as working machines, which both utilised encryption of their hard disc drives. Both machines were regularly synchronised via a laboratory cloud server on the HAW Hamburg campus which was accessed via the author's password-protected user account. With the submission of this thesis, however, the synchronisation folder has been removed and the data is only stored as a backup on the author's desktop computer. Only the author is in possession of the password to access this storage.

3.7 Summary

This chapter elaborated on the foundations of the present research. Section 3.2 started with illustrations regarding philosophical and methodological choices. It highlighted decisions made in terms of the chosen philosophical stance (i.e. pragmatism), the research strategy (i.e. classic GT), data collection (i.e. mixed-methods), the time horizon (i.e. longitudinal), and finally, the techniques and procedures selected. Subsequently, Section 3.3 presented the setting in which the research was conducted. Section 3.4

[17] https://en.evasys.de/main/home.html

then continued with an introduction to the Ambient Surfaces solution. The chapter proceeded with Section 3.5, including a reflection on the author's role in the present research. Finally, the preceding text illustrated ethical considerations in Section 3.6.

Chapter 4 now continues with the results of this research, which were obtained by applying the mechanisms described above.

Chapter 4

Results

> An exemplary indicator that initially pinpointed the emergent core category of *Spontaneous utilisation*: "... I used it [the first Ambient Surface] as well. However, not regularly, but actually more in spontaneous occasions when I walk past it."
>
> —*Mr Blue*, group interview participant in *Phase 2*

4.1 Introduction

This chapter returns to the fourth and last step in the systematisation approach of the constant comparison process (see Section 3.2.5.2). It continues with a presentation of the results of each of the four introduced research phases and highlights how each of these phases conceptually and theoretically contributed towards the process of generating theory. Therefore, Section 4.2 begins with the investigation of quantitative

interaction data (i.e. *Phase 1*). Then, Section 4.3 proceeds with *Phase 2*, which incorporated largely qualitative data stemming from observations, a group interview, and an online survey. The chapter continues with *Phase 3* in Section 4.4, where analyses were carried out based on long-term interaction data. Following that, Section 4.5 outlines how data stemming from a respondent validation concurred with and contradicted the proposed theory (i.e. *Phase 4*). Finally, Section 4.6 concludes and summarises this chapter.

A list of translations of utilised in-text passages is provided in Appendix E. Furthermore, overviews of the proposed hypotheses and emergent questions presented in this chapter are included in Appendix F.1 and F.2 respectively.

4.2 *Phase 1*: Interaction Data

Phase 1 commenced by preparing the relevant log file for analysis. To this end, unnecessary lines such as labelling information were removed from the file. Each analysis was also constrained to one specific type of event. Generally, each finger was registered as one *touch down* event (i.e. a person places a finger on the surface), one *touch up* event (i.e. a person lifts a finger from the surface), and at least one *touch move* event (i.e. a person moves a finger across the surface) in the software framework. In *Phase 1*, it is the timestamp of an interaction that was relevant and not, for instance, its duration (i.e. how long a person left a finger on the surface). This is due to the fact that it was intended to focus on investigating when and not for how long people utilised the first Ambient Surface. Thus, touch move events were excluded from analysis. Additionally, as both touch down events and touch up events yielded the same information with respect to the number of their occurrences, it was decided to concentrate on touch down events during analysis in *Phase 1*. The described steps decreased the total number of log file lines from 828,221 to 22,074 for the entire year of 2014. In terms of calendar weeks (starting on Mondays and ending on Sundays), this included weeks 8 to 52. As displaying all cross-tabulations and discussing them in forensic detail would make a quantitative GT report unreadable, Glaser (2008) recommends that researchers should

consider some liberties when presenting their data[1]. Accordingly, "it is sufficient to report plausible relationships between variables and not to develop a strong case for each relationship" (Glaser, 2008, p. 63). Overall, the 2014 analyses were organised in four stages (labelled *Stage 1* to *Stage 4*), while each of these stages concerned interaction data from several weeks. This organisation was a result of events that occurred throughout this time period. The stages were concluded with a subsequent retrospective analysis.

4.2.1 *Stage 1*: The First Days

Since the Ambient Surface went operational on a Friday just before midday, there was roughly half a working day in Week 8 left to be analysed. Thus, it was decided to initiate the analysis by covering the first 2 weeks (i.e. 6 working days) in *Stage 1*. Figure 4.1 shows the data[2] gathered throughout weeks 8 and 9. For clarity reasons, different colours are utilised henceforth in these illustrations. While dark blue segments indicate strong usage, white segments indicate the opposite. It was anticipated that the novelty effect heavily influenced the usage during this time. Thus, a strong focus was placed on identifying the first prominent patterns in the data.

When combining weeks 8 and 9 and comparing their varying segments, there was an observable strong relationship between the items *Number of interactions* and *Times of day* between 12:00 and 14:00. There were also peaks in usage in the afternoon, for example, starting at 16:00. Nonetheless, interactions were apparently spread diversely across a whole day. A noticeable number of interactions also occurred in the morning (e.g. between 08:00 and 09:00 or at 10:30). Evidently, there were times of day in which interactions notably lowered in numbers compared to preceding time slots (e.g. at 09:30, 11:00, 14:30, and 15:30). In summary, the findings led to the idea that events such as arriving at work may somewhat theoretically relate to usage. Based on the evidence presented in *Stage 1*, the following first hypotheses were stated:

[1] Such recommendations can also be found in terms of qualitative GT (e.g. Corbin and Strauss, 2015).
[2] The illustrated data is calculated with a built-in function from the spreadsheet software. This function ensured that a given timestamp was rounded to its nearest half-hourly segment. For example, interactions occurring between 11:45:00 and 12:14:59 were consequently incorporated in the segment *12:00*, whereas interactions between 11:15:00 and 11:44:59 were counted as part of the segment *11:30*.

Times of day	# of	# of (in %)
07:00	0	0.00%
07:30	0	0.00%
08:00	0	0.00%
08:30	0	0.00%
09:00	0	0.00%
09:30	0	0.00%
10:00	0	0.00%
10:30	0	0.00%
11:00	0	0.00%
11:30	0	0.00%
12:00	167	8.96%
12:30	161	8.64%
13:00	259	13.90%
13:30	302	16.21%
14:00	317	17.02%
14:30	27	1.45%
15:00	61	3.27%
15:30	5	0.27%
16:00	24	1.29%
16:30	208	11.16%
17:00	176	9.45%
17:30	36	1.93%
18:00	120	6.44%
18:30	0	0.00%
19:00	0	0.00%
19:30	0	0.00%
20:00	0	0.00%
Total:	**1,863**	**100.00%**

Week 8

Times of day	# of	# of (in %)
07:00	0	0.00%
07:30	47	1.22%
08:00	139	3.62%
08:30	155	4.03%
09:00	194	5.05%
09:30	83	2.16%
10:00	117	3.04%
10:30	293	7.62%
11:00	113	2.94%
11:30	146	3.80%
12:00	324	8.43%
12:30	184	4.79%
13:00	330	8.58%
13:30	213	5.54%
14:00	234	6.09%
14:30	159	4.14%
15:00	195	5.07%
15:30	86	2.24%
16:00	215	5.59%
16:30	128	3.33%
17:00	109	2.83%
17:30	125	3.25%
18:00	122	3.17%
18:30	97	2.52%
19:00	37	0.96%
19:30	0	0.00%
20:00	0	0.00%
Total:	**3,845**	**100.00%**

Week 9

Times of day	# of	# of (in %)
07:00	0	0.00%
07:30	47	0.82%
08:00	139	2.44%
08:30	155	2.72%
09:00	194	3.40%
09:30	83	1.45%
10:00	117	2.05%
10:30	293	5.13%
11:00	113	1.98%
11:30	146	2.56%
12:00	491	8.60%
12:30	345	6.04%
13:00	589	10.32%
13:30	515	9.02%
14:00	551	9.65%
14:30	186	3.26%
15:00	256	4.48%
15:30	91	1.59%
16:00	239	4.19%
16:30	336	5.89%
17:00	285	4.99%
17:30	161	2.82%
18:00	242	4.24%
18:30	97	1.70%
19:00	37	0.65%
19:30	0	0.00%
20:00	0	0.00%
Total:	**5,708**	**100.00%**

Weeks 8–9

Figure 4.1: Three instances of the crude index *Utilisation of the Ambient Surface*, collating evidence from Week 8 (left), Week 9 (centre), and weeks 8 and 9 in combination (right).

- H_1: The Ambient Surface is notably utilised in the early morning when people are arriving at work.
- H_2: The Ambient Surface is mostly utilised when people are going to or are returning from lunch.
- H_3: The Ambient Surface is notably utilised in the late afternoon when people are leaving work.
- H_4: There are times of day in which the use of the Ambient Surface notably decreases.
- H_5: A novelty effect results in a wide-spread usage of the Ambient Surface across a whole day.

Times of day	# of	# of (in %)
07:00	0	0.00%
07:30	47	0.82%
08:00	139	2.44%
08:30	155	2.72%
09:00	194	3.40%
09:30	83	1.45%
10:00	117	2.05%
10:30	293	5.13%
11:00	113	1.98%
11:30	146	2.56%
12:00	491	8.60%
12:30	345	6.04%
13:00	589	10.32%
13:30	515	9.02%
14:00	551	9.65%
14:30	186	3.26%
15:00	256	4.48%
15:30	91	1.59%
16:00	239	4.19%
16:30	336	5.89%
17:00	285	4.99%
17:30	161	2.82%
18:00	242	4.24%
18:30	97	1.70%
19:00	37	0.65%
19:30	0	0.00%
20:00	0	0.00%
Total:	5,708	100.00%

Weeks 8–9

Times of day	# of	# of (in %)
07:00	0	0.00%
07:30	38	2.12%
08:00	77	4.29%
08:30	94	5.24%
09:00	74	4.13%
09:30	192	10.71%
10:00	83	4.63%
10:30	65	3.63%
11:00	35	1.95%
11:30	102	5.69%
12:00	79	4.41%
12:30	79	4.41%
13:00	63	3.51%
13:30	138	7.70%
14:00	42	2.34%
14:30	34	1.90%
15:00	146	8.14%
15:30	76	4.24%
16:00	107	5.97%
16:30	30	1.67%
17:00	76	4.24%
17:30	69	3.85%
18:00	45	2.51%
18:30	33	1.84%
19:00	7	0.39%
19:30	0	0.00%
20:00	9	0.50%
Total:	1,793	100.00%

Week 10

Times of day	# of	# of (in %)
07:00	3	0.12%
07:30	12	0.49%
08:00	24	0.98%
08:30	104	4.25%
09:00	131	5.36%
09:30	117	4.78%
10:00	194	7.93%
10:30	76	3.11%
11:00	318	13.00%
11:30	70	2.86%
12:00	66	2.70%
12:30	74	3.03%
13:00	192	7.85%
13:30	161	6.58%
14:00	183	7.48%
14:30	31	1.27%
15:00	116	4.74%
15:30	76	3.11%
16:00	161	6.58%
16:30	31	1.27%
17:00	92	3.76%
17:30	129	5.27%
18:00	40	1.64%
18:30	34	1.39%
19:00	1	0.04%
19:30	10	0.41%
20:00	0	0.00%
Total:	2,446	100.00%

Week 11

Times of day	# of	# of (in %)
07:00	3	0.03%
07:30	97	0.98%
08:00	240	2.41%
08:30	353	3.55%
09:00	399	4.01%
09:30	392	3.94%
10:00	394	3.96%
10:30	434	4.36%
11:00	466	4.68%
11:30	318	3.20%
12:00	636	6.39%
12:30	498	5.01%
13:00	844	8.48%
13:30	814	8.18%
14:00	776	7.80%
14:30	251	2.52%
15:00	518	5.21%
15:30	243	2.44%
16:00	507	5.10%
16:30	397	3.99%
17:00	453	4.55%
17:30	359	3.61%
18:00	327	3.29%
18:30	164	1.65%
19:00	45	0.45%
19:30	10	0.10%
20:00	9	0.09%
Total:	9,947	100.00%

Weeks 8–11

Figure 4.2: Four instances of the crude index *Utilisation of the Ambient Surface*, illustrating a summation of evidence from weeks 8 to 9 (left), in contrast to data from Week 10 (second to left), Week 11 (second to right), and weeks 8 to 11 (right).

The predominant question that subsequently arose was: how would these emergent patterns manifest (i.e. saturate) in the future? Thus, further data was sought in order to develop a more comprehensive understanding. Overall, the sampling strategy was not revised subsequent to *Stage 1*.

4.2.2 *Stage 2*: Novelty and Changes

Stage 2 considered the data gathered throughout weeks 10 and 11. The reason for this was twofold: firstly, a planned update in the form of the new *Confluence* view was deployed in Week 11; secondly, Week 11 had marked the end of the reported novelty effect's overall predominance in some previous studies (e.g. Gallacher et al., 2015; Hazlewood, Stolterman, and Connelly, 2011).

Principally, *Stage 2* concerned the question of how the processes of adding new features or revising existing ones affect usage. To elaborate on this question, Figure 4.2 displays the data from *Stage 1* and compares it with weeks 10 and 11 as well as the accumulated data from weeks 8 to 11. The most notable difference in Week 11 is the high

number of interactions at around 11:00. However, by triangulating the interaction data with emails, this incident could be pinpointed to an evaluation activity from an employee. Generally, an increase in interactions was noted in Week 11 (2,446 interactions compared to 1,793 interactions in Week 10). Hence, changes to the system apparently resulted in a substantial difference in the total number of interactions. Although some variances occurred, the observed weeks share similarities to some extent with regard to interactions in the morning, at noon, and in the afternoon. Evidently, the accumulated data from weeks 8 to 11 indicated that interaction segments during the day started to blend together. Furthermore, compared to their preceding segments, the number of interactions remained comparably small, for example, at 14:30 and 15:30.

In conclusion, fundamental patterns from the first 2 weeks seemed to manifest. It was likely that the novelty effect continued to have a strong influence on the measurement figures. Thus, it was hardly possible to hypothesise that the present material showed some extent of saturation. There was also no strong evidence to reject any of the aforesaid hypotheses. What was weakly evident, however, was the notion that changes to the system affected the total number of interactions. Hence, a further hypothesis was proposed:

- H_6: Changes to an existing system contribute towards or extend a prevalent novelty effect.

During *Stage 2*, it was decided to continue data collection and analysis with the fundamental question of pattern development and the hitherto stated hypotheses in mind. However, the question became: how might these seemingly developing patterns change in the future when going beyond the reported terrain of novelty?

4.2.3 *Stage 3*: Leaving the Terrain of Novelty

Stage 3 focused on a longer time period (i.e. weeks 12 to 19). This was because of two main reasons. Firstly, while comparing the weeks in question, it was found that weeks 8 to 11 showed a higher number of interactions. While weeks 8 to 11 in summary accounted for 9,947 interactions, weeks 12 to 19 showed a total of 6,686 interactions. Secondly, a 5-week period (i.e. weeks 20 to 24) followed in which the Ambient Surface

Times of day	# of	# of (in %)
07:00	3	0.03%
07:30	97	0.98%
08:00	240	2.41%
08:30	353	3.55%
09:00	399	4.01%
09:30	392	3.94%
10:00	394	3.96%
10:30	434	4.36%
11:00	466	4.68%
11:30	318	3.20%
12:00	636	6.39%
12:30	498	5.01%
13:00	844	8.48%
13:30	814	8.18%
14:00	776	7.80%
14:30	251	2.52%
15:00	518	5.21%
15:30	243	2.44%
16:00	507	5.10%
16:30	397	3.99%
17:00	453	4.55%
17:30	359	3.61%
18:00	327	3.29%
18:30	164	1.65%
19:00	45	0.45%
19:30	10	0.10%
20:00	9	0.09%
Total:	**9,947**	**100.00%**

Weeks 8–11

Times of day	# of	# of (in %)
07:00	4	0.06%
07:30	32	0.48%
08:00	78	1.17%
08:30	290	4.34%
09:00	195	2.92%
09:30	288	4.31%
10:00	103	1.54%
10:30	178	2.66%
11:00	365	5.46%
11:30	293	4.38%
12:00	468	7.00%
12:30	250	3.74%
13:00	267	3.99%
13:30	306	4.58%
14:00	427	6.39%
14:30	462	6.91%
15:00	398	5.95%
15:30	369	5.52%
16:00	339	5.07%
16:30	489	7.31%
17:00	379	5.67%
17:30	115	1.72%
18:00	401	6.00%
18:30	46	0.69%
19:00	114	1.71%
19:30	30	0.45%
20:00	0	0.00%
Total:	**6,686**	**100.00%**

Week 12–19

Times of day	# of	# of (in %)
07:00	7	0.04%
07:30	129	0.78%
08:00	318	1.91%
08:30	643	3.87%
09:00	594	3.57%
09:30	680	4.09%
10:00	497	2.99%
10:30	612	3.68%
11:00	831	5.00%
11:30	611	3.67%
12:00	1,104	6.64%
12:30	748	4.50%
13:00	1,111	6.68%
13:30	1,120	6.73%
14:00	1,203	7.23%
14:30	713	4.29%
15:00	916	5.51%
15:30	612	3.68%
16:00	846	5.09%
16:30	886	5.33%
17:00	832	5.00%
17:30	474	2.85%
18:00	728	4.38%
18:30	210	1.26%
19:00	159	0.96%
19:30	40	0.24%
20:00	9	0.05%
Total:	**16,633**	**100.00%**

Weeks 8–19

Figure 4.3: Three instances of the crude index *Utilisation of the Ambient Surface*, incorporating data from weeks 8 to 11 (left), compared to material from weeks 12 to 19 (centre), and weeks 8 to 19 (right).

was largely not operational due to software-related issues. Hence, it felt reasonable to concentrate solely on weeks 12 to 19 during that time. To investigate whether there were any changes to already identified patterns, data from weeks 8 to 11, weeks 12 to 19, and the accumulated data from weeks 8 to 19 were compared (see Figure 4.3).

When comparing the data from weeks 8 to 11 with weeks 12 to 19, three outcomes became apparent. Firstly, in weeks 12 to 19, the segments of interactions in the morning vary more diversely (i.e. between 08:30 and 11:00). Secondly, in weeks 8 to 11, there was a stronger prevalence of interactions between 12:00 and 14:00. Thirdly, interactions in the afternoon in weeks 12 to 19 were comparatively more equally spread between 14:00 and 17:00. When analysing the accumulated data from weeks 8 to 19, it was apparent that there were still times of day in which more interactions with the Ambient Surface occurred (i.e. in the early morning, noon, and late afternoon). There were also still

times in which the number of interactions remained comparably low (i.e. at 14:30 and 15:30). Finally, it became questionable whether the conjecture of hypothesis H_5 remained valid. For example, when looking at data from weeks 12 to 19, interactions were still well distributed across the day. As for the other hypotheses (i.e. H_1 to H_4 and H_6), there was no strong evidence to reject any of them at a given point in time.

In conclusion, after 12 weeks into the field study, it was fair to say that after 19:00 there were no more substantial occurrences of interactions. In the morning, this was the case for the time prior to 07:30. With respect to display blindness, it could be concluded that the Ambient Surface was still frequently being utilised. Although the total number of interactions decreased notably in weeks 12 to 19, which was to some extent anticipated, the system was seemingly incorporating positive contributing factors. Otherwise, it felt that the usage would have dropped more substantially or would have halted entirely during this time period. Consequently, the following hypothesis was defined:

- H_7: The Ambient Surface provides positive contributing factors beyond a prevalent novelty effect.

This hypothesis simultaneously raised the question of what these positive contributing factors actually were. However, such an investigation was beyond the scope of analysing interaction data. When considering the question surrounding developing patterns beyond the reported terrain of novelty, it seemed questionable that a sufficient amount of data had been collected to show utilisation despite both the novelty effect (e.g. following changes in Week 15) and display blindness (e.g. a potential threat of disuse due to the subsequent 5-week period of inactivity). It was then decided to continue collecting and analysing interaction data in order to gather more comparable material.

4.2.4 *Stage 4*: Threats Connected with Display Blindness

Of particular interest in *Stage 4* was whether the Ambient Surface could overcome threats stemming from display blindness and whether previously obtained patterns would endure over time. Consequently, it was decided to focus on analysing interaction data until the end of the year. The reason for this decision was threefold: firstly, to

Times of day	# of	# of (in %)
07:00	3	0.03%
07:30	97	0.98%
08:00	240	2.41%
08:30	353	3.55%
09:00	399	4.01%
09:30	392	3.94%
10:00	394	3.96%
10:30	434	4.36%
11:00	466	4.68%
11:30	318	3.20%
12:00	636	6.39%
12:30	498	5.01%
13:00	844	8.48%
13:30	814	8.18%
14:00	776	7.80%
14:30	251	2.52%
15:00	518	5.21%
15:30	243	2.44%
16:00	507	5.10%
16:30	397	3.99%
17:00	453	4.55%
17:30	359	3.61%
18:00	327	3.29%
18:30	164	1.65%
19:00	45	0.45%
19:30	10	0.10%
20:00	9	0.09%
Total:	**9,947**	**100.00%**

Weeks 8–11

Times of day	# of	# of (in %)
07:00	4	0.06%
07:30	32	0.48%
08:00	78	1.17%
08:30	290	4.34%
09:00	195	2.92%
09:30	288	4.31%
10:00	103	1.54%
10:30	178	2.66%
11:00	365	5.46%
11:30	293	4.38%
12:00	468	7.00%
12:30	250	3.74%
13:00	267	3.99%
13:30	306	4.58%
14:00	427	6.39%
14:30	462	6.91%
15:00	398	5.95%
15:30	369	5.52%
16:00	339	5.07%
16:30	489	7.31%
17:00	379	5.67%
17:30	115	1.72%
18:00	401	6.00%
18:30	46	0.69%
19:00	114	1.71%
19:30	30	0.45%
20:00	0	0.00%
Total:	**6,686**	**100.00%**

Weeks 12–19

Times of day	# of	# of (in %)
07:00	7	0.14%
07:30	67	1.31%
08:00	41	0.80%
08:30	142	2.78%
09:00	201	3.94%
09:30	154	3.02%
10:00	280	5.48%
10:30	252	4.94%
11:00	173	3.39%
11:30	176	3.45%
12:00	285	5.58%
12:30	620	12.14%
13:00	255	4.99%
13:30	363	7.11%
14:00	194	3.80%
14:30	290	5.68%
15:00	301	5.90%
15:30	164	3.21%
16:00	265	5.19%
16:30	296	5.80%
17:00	238	4.66%
17:30	161	3.15%
18:00	93	1.82%
18:30	32	0.63%
19:00	34	0.67%
19:30	18	0.35%
20:00	4	0.08%
Total:	**5,106**	**100.00%**

Weeks 20–52

Figure 4.4: Three instances of the crude index *Utilisation of the Ambient Surface*, including data from weeks 8 to 11 (left), in comparison to data from weeks 12 to 19 (centre), and weeks 20 to 52 (right).

allow a profound comparison with an extensive amount of usage data; secondly, as the Ambient Surface was last revised in Week 16 and the project partner was still occasionally reviewing its content, it was hypothesised that to fully capture any issues relating to display blindness, more time had to pass; lastly, the almost entirely non-operational state of the screen in weeks 20 to 24 could have subsequently resulted in simple disuse of the system. Figure 4.4 compares the data collected in weeks 8 to 11 to weeks 12 to 19 and weeks 20 to 52. Apparently, the total number of interactions decreased notably from 9,947 interactions (i.e. weeks 8 to 11) to 6,686 interactions (i.e. weeks 12 to 19) and, finally, to 5,106 interactions (i.e. weeks 20 to 52).

In terms of differences among the data, all three cross-tabulations in Figure 4.4 indicated unique points in time regarding the highest number of interactions (i.e. weeks

8 to 11 at 13:00, weeks 12 to 19 at 16:30, and weeks 20 to 52 at 12:30). At the same time, with 12.14% of all interactions, the latter incident represents the largest peak in interactions across all three illustrations and was the only two-digit percentage figure in the cross-tabulations. Further differences could be revealed by comparing higher drops of interactions in all three illustrations (i.e. > 50 interactions). Weeks 8 to 11 provided such reductions at 14:30, 16:30, and 19:00. Weeks 12 to 19 indicated such drops at 09:00, 10:00, 15:00, and 19:30. Finally, weeks 20 to 52 showed drops by at least 51 interactions at 11:00, 13:00, 14:00, and 18:00. Interestingly, weeks 8 to 11 and weeks 12 to 19 shared a higher number of segments suggesting very strong usage (i.e. dark blue colours) compared to one segment in weeks 20 to 52. A possible explanation for this finding could be the prevalence of the novelty effect in these weeks.

When looking at similarities, it became apparent that interactions in all three illustrations dropped by at least 51 interactions starting at 17:30. Also, weeks 8 to 11 and weeks 20 to 52 shared such decreases in interactions at 15:30. Likewise, weeks 12 to 19 and weeks 20 to 52 showed drops at 17:00. Weeks 8 to 11 and weeks 12 to 19 shared declines at 11:30 and 12:30. However, despite these varying magnitudes of interaction reductions, the question of what causes them in the first place started to emerge. It was found that the present material was unable to address this issue. As a result of these declines, hypothesis H_4 was becoming somewhat substantiated. The opposite seemed to be the case for hypothesis H_5, since the influence of a novelty effect was now arguably small and interactions continued to be spread across a whole day. In an attempt to rephrase hypothesis H_5, the following was stated:

- H_5 (reformulated): A novelty effect results in the usage of the Ambient Surface which distracts from latent patterns due to the magnitude of interactions and the time of their occurrence.

Hypotheses H_1, H_2, H_3, and H_7 were supported by the findings. There were still measurable peaks of interactions in the early morning, on midday, and in the late afternoon (i.e. hypotheses H_1–H_3). It was further believed that the use of the Ambient Surface would have halted if the magnitude of display blindness had been too large (i.e. hypothesis H_7). Arguably, the results obtained in weeks 20 to 52 were more likely to

Times of day	# of	# of (in %)
07:00	0	0.00%
07:30	40	2.03%
08:00	3	0.15%
08:30	64	3.24%
09:00	111	5.63%
09:30	50	2.53%
10:00	83	4.21%
10:30	133	6.74%
11:00	69	3.50%
11:30	21	1.06%
12:00	107	5.42%
12:30	128	6.49%
13:00	45	2.28%
13:30	214	10.85%
14:00	99	5.02%
14:30	89	4.51%
15:00	157	7.96%
15:30	107	5.42%
16:00	143	7.25%
16:30	34	1.72%
17:00	125	6.34%
17:30	90	4.56%
18:00	20	1.01%
18:30	30	1.52%
19:00	6	0.30%
19:30	3	0.15%
20:00	2	0.10%
Total:	**1,973**	**100.00%**

Weeks 21–30

Times of day	# of	# of (in %)
07:00	0	0.00%
07:30	18	1.38%
08:00	13	0.99%
08:30	34	2.60%
09:00	35	2.68%
09:30	62	4.74%
10:00	39	2.98%
10:30	28	2.14%
11:00	63	4.82%
11:30	13	0.99%
12:00	75	5.74%
12:30	166	12.70%
13:00	81	6.20%
13:30	114	8.72%
14:00	30	2.30%
14:30	100	7.65%
15:00	55	4.21%
15:30	11	0.84%
16:00	90	6.89%
16:30	128	9.79%
17:00	12	0.92%
17:30	48	3.67%
18:00	57	4.36%
18:30	2	0.15%
19:00	26	1.99%
19:30	7	0.54%
20:00	0	0.00%
Total:	**1,307**	**100.00%**

Weeks 31–40

Times of day	# of	# of (in %)
07:00	7	0.38%
07:30	9	0.49%
08:00	25	1.37%
08:30	44	2.41%
09:00	55	3.01%
09:30	42	2.30%
10:00	158	8.65%
10:30	91	4.98%
11:00	41	2.25%
11:30	142	7.78%
12:00	103	5.64%
12:30	326	17.85%
13:00	129	7.06%
13:30	35	1.92%
14:00	65	3.56%
14:30	101	5.53%
15:00	89	4.87%
15:30	46	2.52%
16:00	32	1.75%
16:30	134	7.34%
17:00	101	5.53%
17:30	23	1.26%
18:00	16	0.88%
18:30	0	0.00%
19:00	2	0.11%
19:30	8	0.44%
20:00	2	0.11%
Total:	**1,826**	**100.00%**

Weeks 41–50

Figure 4.5: Three instances of the crude index *Utilisation of the Ambient Surface*, incorporating data from weeks 21 to 30 (left), compared to data from weeks 31 to 40 (centre), and weeks 41 to 50 (right).

indicate usage when compared to data from the preceding weeks. Nonetheless, there were still similarities across all illustrations, although a novelty effect had likely affected results gathered in the first weeks.

In conclusion, threats resulting from display blindness were possibly prevalent to some extent, but were also beyond the scope of investigation. What was evident was that employees continued utilising the Ambient Surface. However, with the available data at hand, only usage in the form of interactions was measurable—although most likely relevant, passive use had not been considered so far. An analysis of data stemming from weeks 21 to 30, weeks 31 to 40, and 41 to 50 (see Figure 4.5) indicated that similarities in patterns now became sufficiently saturated to seek further material to be incorporated and hence to strengthen theoretical sensitivity. It could be found that:

- Markedly strong usage evidently only appeared in one instance (i.e. segments with a dark blue colour and the only two-digit percentage values). Novelty seemingly ceased to affect the usage to a notable degree as these findings contradicted results from earlier weeks, such as those depicted in Figure 4.3 (i.e. several segments of strong usage). It was hypothesised that such pattern observations will not dramatically change in the future, considering there were no substantial changes to the system which in turn would provoke a novelty effect. Furthermore, a sufficient amount of time had passed and employees were arguably familiar with the system at this point in time.

- Segments of stronger usage were present in the morning, afternoon, and evening in all illustrations. These peaks in usage varied, but it was expected that such patterns would recur. It felt reasonable to assume that these varying increases in interactions originated in the complex nature of the field deployment. The versatility of events that arise from such a context is arguably beyond anyone's control. This likewise posed the challenge to depict a certain time period that demonstrated data saturation most accurately. However, it was felt that more data would likely reveal similar patterns as seen in weeks 21 to 30, weeks 31 to 40, and weeks 41 to 50.

4.2.5 2014: A Retrospective

Before *Phase 1* was concluded, two further issues were retrospectively investigated. Firstly, a graphic was created in the form of a diagram relating to the all-year usage in terms of interactions per week (see Figure 4.6). Secondly, it was intended to investigate data representativeness in a further analysis (see Figure 4.7).

Considering all the available interaction data from 2014 (i.e. excluding weekends and including weeks with no interaction data), it was found that the mean number of interactions per week first fell below the all-year mean of interactions (circa 483 interactions) in Week 18 (455 interactions). Additionally, the first 4 weeks had the highest amount of interactions across the entire year. Generally, the first weeks after the deployment were in stark contrast to weeks later in the year. Also, staff members

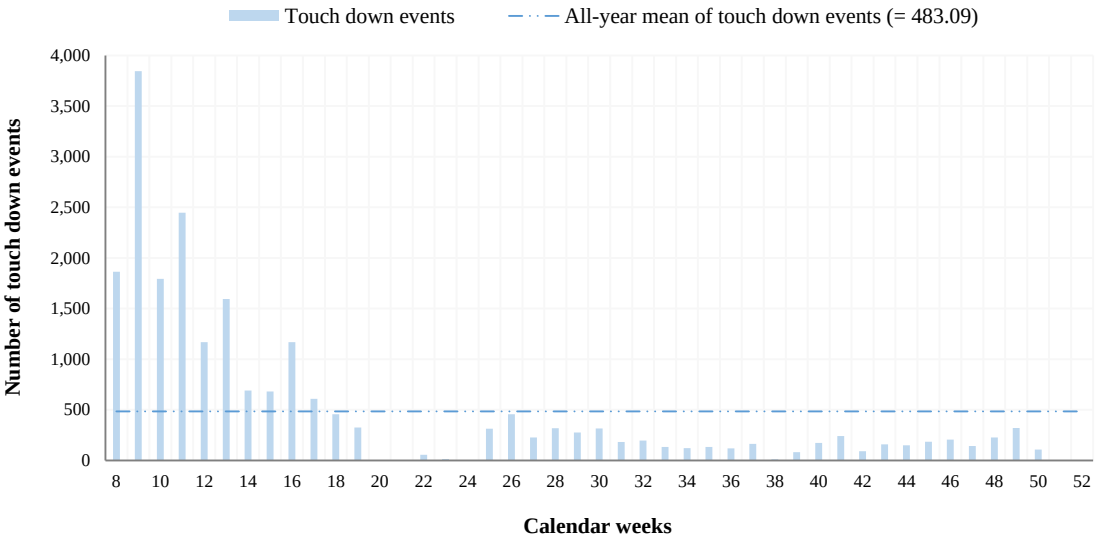

Figure 4.6: The number of touch down events (21,739 in total) in weeks 8 to 52 in 2014.

continued to use the system after the breakdown in operation in weeks 20 to 24. Returning to the issue of data representativeness, Figure 4.7 shows a tabular overview of gathered material in weeks 18 to 52. The aim of this investigation was to reveal events that may have substantially affected measurements. To approach this investigation, it was decided to leverage the following variables for comparisons:

1. The time of day segments (labelled A),
2. the total number of interactions (labelled B),
3. the highest instance of interactions on a single day (labelled C),
4. a percentage figure relating C to B (labelled D),
5. and finally, the number of days that included at least one interaction (labelled E).

Principally, a high value of D would have suggested that there were indeed single occasions which substantially affected the results. However, the value of D was the highest prior to 08:30 and after 17:30 (i.e. 33.33% and higher). During these time frames, the value E was the lowest (i.e. ranging from 2 to 13 days). It was fair to say that these findings were somewhat relatable to the company's business hours. In contrast, between 08:30 and 17:30, the value E did not fall below a total of 19 days.

A	B	C	D	E
07:00	9	4	44.44%	3
07:30	70	34	48.57%	10
08:00	43	21	48.84%	13
08:30	173	32	18.50%	19
09:00	254	28	11.02%	27
09:30	163	44	26.99%	21
10:00	306	43	14.05%	37
10:30	274	51	18.61%	27
11:00	268	45	16.79%	31
11:30	225	58	25.78%	26
12:00	297	31	10.44%	41
12:30	653	45	6.89%	48
13:00	267	33	12.36%	34
13:30	416	92	22.12%	30
14:00	213	25	11.74%	36
14:30	342	55	16.08%	32
15:00	352	44	12.50%	32
15:30	185	32	17.30%	21
16:00	285	36	12.63%	27
16:30	406	60	14.78%	33
17:00	275	41	14.91%	30
17:30	176	32	18.18%	22
18:00	113	50	44.25%	13
18:30	48	16	33.33%	6
19:00	51	26	50.98%	8
19:30	18	7	38.89%	5
20:00	4	2	50.00%	2
Total:	**5,886**			

A	B	C	D	E
07:00	9	4	44.44%	3
07:30	70	34	48.57%	10
08:00	43	21	48.84%	13
08:30	173	32	18.50%	19
09:00	254	28	11.02%	27
09:30	163	44	26.99%	21
10:00	306	43	14.05%	37
10:30	274	51	18.61%	27
11:00	268	45	16.79%	31
11:30	225	58	25.78%	26
12:00	297	31	10.44%	41
12:30	653	45	6.89%	48
13:00	267	33	12.36%	34
13:30	416	92	22.12%	30
14:00	213	25	11.74%	36
14:30	342	55	16.08%	32
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17:30	176	32	18.18%	22
18:00	113	50	44.25%	13
18:30	48	16	33.33%	6
19:00	51	26	50.98%	8
19:30	18	7	38.89%	5
20:00	4	2	50.00%	2
Total:	**5,886**			

Weeks 18–52

Figure 4.7: Left: Time of day segments (A) in relation to the total number of interactions (B), the highest instance of interactions on a single day (C), a percentage figure relating C to B (D), and finally, the number of days that included at least one interaction (E). Right: The same parameters with respect to the five highest values (i.e. regarding A, B, C, and E) and the five lowest values regarding D.

The comparison principally revealed that the Ambient Surface was seemingly used regularly across the selected time frame, including a total of 120 working days. Interestingly, the highest magnitude of B (i.e. 653 interactions) was related to the highest value of E (i.e. 48 days) and the lowest value of D (i.e. 6.89%). Additionally, the segment was followed by the highest decline in interactions (i.e. 386 interactions). It could thus be argued that the Ambient Surface was utilised on most days at around 12:30. Hence, hypothesis H_2 showed a somewhat particular relevance.

In summary, it was not evident that the results in weeks 18 to 52 were substantially affected by any single incident. It felt that the presented findings showed somewhat authentic usage beyond both the prevalence of a novelty effect and threats relating to display blindness.

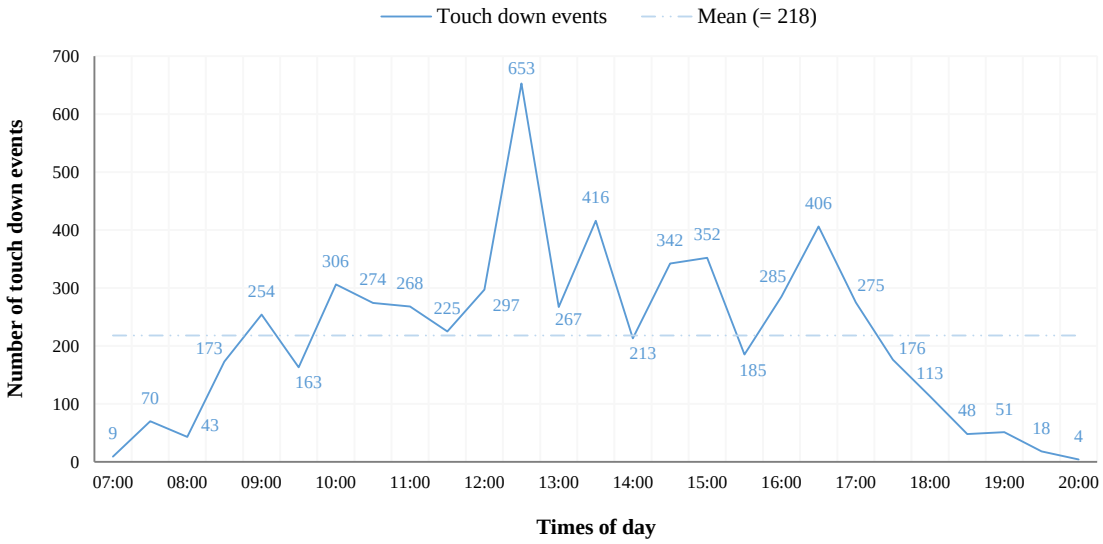


Figure 4.8: Touch down events (5,886 in total) with respect to the corresponding times of day for weeks 18 to 52 in 2014.

4.2.6 Conclusion

The remainder of this section ends with a conclusion of *Phase 1*. Overall, *Phase 1* marked the first conclusive stepping stone towards a grounded understanding of the Ambient Surface's long-term usage on a conceptual and theoretical level. Arguably, *Phase 1* was limited to indicate what Muller and Kogan (2012, p. 1013) describe as the "focal topic" of a research enterprise. Nonetheless, the findings from *Phase 1* suggest that utilisation is somewhat notably related to informal events (e.g. lunch time). In sum, seven theoretical codes were proposed in *Phase 1* (i.e. hypotheses H_1–H_7).

Addressing the Research Phase Questions

Considering the first question concerning times of day, it could be concluded that the most notable usage of the system could be observed in the early afternoon, foremost at 12:30 (see Figure 4.8). For all other cases, the picture depended on the selected time frame. When comparing the total number of interactions between 07:00 and 12:30 (i.e. 2,735 interactions) with the number of interactions starting at 13:00 (i.e. 3,151 interactions), it became evident that slightly more interactions (i.e. circa 13%) occurred in the second part of a working day. Interactions in the morning were more evenly spread across the first part of the day (e.g. between 08:30 and 11:30 compared to the time between 12:00 and 15:00). However, instances of higher activity in the

morning were less substantial in the total number of interactions compared to occasions in the afternoon (e.g. 08:30 to 09:00, in contrast to 14:30 to 15:00). This issue became substantiated by the fact that the next four highest incidents of activity occurred in the afternoon (i.e. at 13:30, 14:30, 15:00, and 16:30).

With respect to the second question regarding the novelty effect it was found that weeks 18 to 52 were likely no longer affected by novelty. For instance, most interactions occurred in the first 4 weeks. Furthermore, contrary to weeks 18 to 52, weeks 8 to 11 and weeks 12 to 19 (see Figure 4.4) indicated more than just one incident of strong usage (i.e. segments with a dark blue colour). It also became apparent that novelty not only stemmed from the initial experience of exploring the Ambient Surface (i.e. an initial novelty effect), but also from adding new and revising existing content (i.e. a reoccurring novelty effect).

Emergent Questions

Attention is now drawn to questions that were difficult to address when solely considering the interaction data of *Phase 1*. They were, therefore, potential candidates for subsequent investigations. These questions were:

- Q_1: What positive contributing factors does the Ambient Surface promote?
- Q_2: What are the reasons for the varying reductions in interactions throughout a day?
- Q_3: How is the Ambient Surface passively being utilised by staff members?
- Q_4: How do the relationships between variables in Figure 4.7 change when they are incrementally compared to additional interaction data?
- Q_5: What can be learnt with respect to display blindness by utilising further data collection techniques?
- Q_6: How do the conclusions regarding data saturation change when they are compared to additional interaction data from subsequent years?

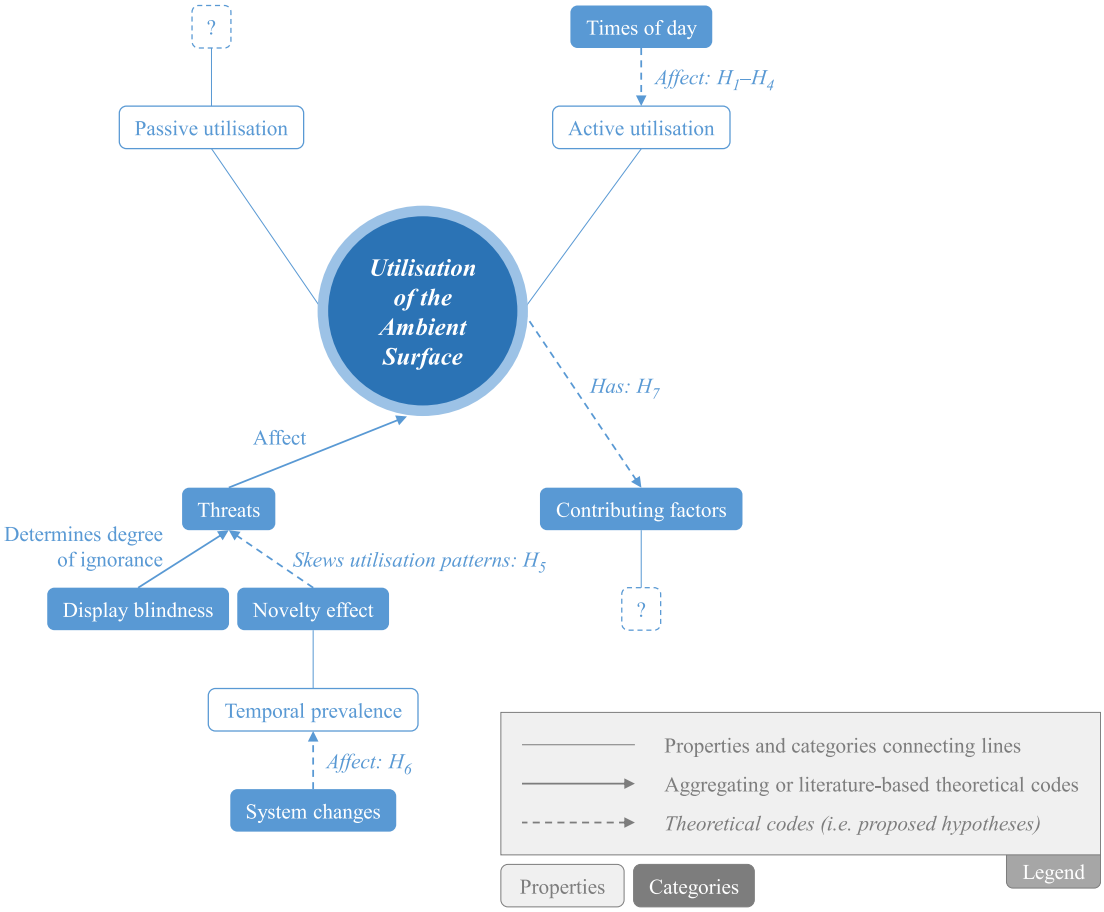


Figure 4.9: A pictorial model of findings in *Phase 1* with the crude index *Utilisation of the Ambient Surface* at its centre, including the seven proposed hypotheses (H_1–H_7).

Pictorial Model of Initial Findings

This section concludes with a first pictorial model that conceptually and theoretically reflects findings from *Phase 1* with the crude index *Utilisation of the Ambient Surface* at its centre (see Figure 4.9). Again, it should be borne that GT researchers are encouraged to both freely design what they wish to present and to write about theory in a substantive manner (Glaser, 1998).

Figure 4.9 concentrates on an abstract hierarchy of interconnected categories in the form of blue rectangles (e.g. the *Novelty effect* category), including corresponding properties in transparent rectangles (e.g. the *Temporal prevalence* property). Arrows leading away from the centre indicate motivational aspects (i.e. the *Contribution factors* category). Arrows that lead towards the centre point to issues that affect utilisation (i.e. the *Threats* category). Dashed arrows indicate theoretical codes (i.e. the proposed hypotheses). Furthermore, all arrows are labelled to indicate relationships. However,

in the case of non-dashed arrows, labels are either informed by the literature (i.e. the *Display blindness* category) or are a product of self-generated aggregating codes (i.e. *Affect* in the *Threats* category), but they do not stem directly from the data. This activity was somewhat similar to what Glaser (1978) refers to as coding of the not-directly-stated in qualitative GT. The depiction also indicates that analyses were limited regarding *Passive utilisation* and *Contributing factors*.

4.3 *Phase 2*: Observational, Interview, and Survey Data

The material used in *Phase 2* required no additional revisions such as the log file in *Phase 1*. However, with respect to observation field notes[3] it was found that the documentation procedure was generally challenging due to the high number of different events. This led to some revisions of the documentation style. For example, after *Day 1* the detail level of information regarding people walking past the Ambient Surface had been reduced. Furthermore, on both *Day 1* and *Day 2* it was retrospectively found that timestamps needed to be more accurate, and subsequently the documentation was enriched accordingly. Also, while the organisation of the field notes helped to relate certain events to particular times of day, it simultaneously lacked granularity. Hence, it was decided to elaborate on the observation findings in 5-minute segments. Whereas observational analyses were rather broadly conducted, analyses regarding the group interview and the online survey incrementally took a more narrowed view towards the data. The following continues with the different (cross-)comparisons conducted throughout *Phase 2*.

4.3.1 Observations: Comparing Times of Day and Noise Levels

The open codes *Noisy* and *Quiet* were created, which were collated under the category *Noise levels*. It was attempted to document incidents in the field notes, where a change in noise levels was noticeable to the author. For example, on *Day 4* it was noted: "11:00: What is happening here? So many people are gathering in the hallway" (i.e. indicator

[3]The 5 days of observation are subsequently labelled *Day 1* to *Day 5*.

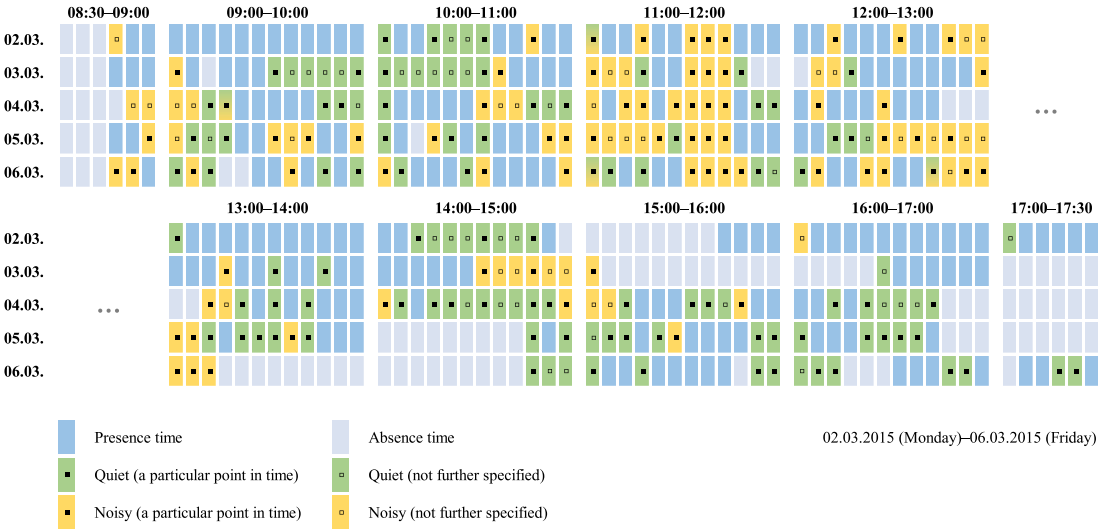


Figure 4.10: A memo including presence (dark blue) and absence (light blue) times as well as data stemming from the denoted noise levels with segments indicating noisier (yellow) and quieter (green) times of day.

of the open code *Noisy*). Figure 4.10 presents data stemming from the category of *Noise levels*. While yellow segments refer to noisier situations (i.e. open code *Noisy*), green segments signify quieter parts of a day (i.e. open code *Quiet*). Data was incorporated into the illustration according to specific given timestamps (i.e. segments with filled square icons) and less specific information (i.e. segments with framed square icons), while the latter includes two cases. Firstly, instances where particular timestamps were related to one another were included (e.g. *Day 2* between 09:30 and 10:00). In such cases, connecting words such as "still" were utilised in field notes, meaning that a situation had not changed. There were, however, examples where no apparent relationship was documented in the field notes. Secondly, cases where the field notes did not provide a specific timestamp were incorporated (e.g. *Day 1* at 08:30).

The noisiest part of the day was between 11:00 and 13:00, where people typically attended meetings (e.g. the Scrum of Scrums meeting between 11:30 and 11:45, Daily Scrum meetings between 11:45 and 12:00, and an update meeting on *Day 4* between roughly 11:00 and 11:15), went to or returned from lunch, and discussed topics in the hallway or in the kitchen. In contrast, it was repeatedly observed that it was sometimes almost completely silent in the building and employees were apparently sitting in their offices. For instance, on *Day 3* it was documented at 14:30: "There are—here and there—discussions in the offices, however, it is generally quiet in the building" (i.e.

indicator of the open code *Quiet*). Furthermore, the morning hours at around 09:00 were generally another time period in each day in which it was noisier, as people were arriving at work. What followed was a quieter time period until around 10:30. Contrary to the morning hours, the same could not be observed, when people were leaving work. It was apparent that between 13:30 and 14:00, it started to get quieter in the building. Overall, observation data showed that there were alternating noisier and quieter time periods throughout each day.

4.3.2 Observations: Comparing Times of Day and the Numbers of Passers-By

On both *Day 4* and *Day 5* it was decided to additionally create tallies which indicated the number of passers-by in relation to times of day. Every time someone walked past the system, the tallies were revised accordingly. Table 4.1 and Table 4.2 correspondingly show the results from roughly 14 hours of observation. In summary, *Day 4* accounted for 628 incidents, while 486 incidents were registered on *Day 5* (1,114 incidents in total). However, the demonstrated numbers should be considered a minimum. For instance, often many people were simultaneously crossing the system's surrounding area and it was very difficult to maintain an accurate tally.

Principally, most incidents could be observed during lunch time between 12:00 and 13:00 on both days (130 and 98 passers-by respectively). The second highest values on *Day 4* and *Day 5* occurred between 10:00 and 11:00 (90 and 75 passers-by respectively), plus between 13:00 and 14:00 on *Day 4* (90 passers-by). Data was less conclusive with respect to the afternoon, since a notable amount of time was spent on preparing and conducting the group interview and an informal discussion on Thursday starting at 14:00. Nonetheless, these figures put forth the circumstance that the selected installation setup was characterised by a notable number of passers-by.

Table 4.1: The tally created on *Day 4*, showing times of day in relation to the number of passers-by and the time in minutes, where no observations were conducted (e.g. due to an informal discussion).

Times of day	**Number of passers-by**	**Number of passers-by (in %)**	**Not observing (in minutes)**
08:45–09:00	45	7.17	0
09:00–10:00	73	11.62	0
10:00–11:00	90	14.33	5
11:00–12:00	70	11.15	0
12:00–13:00	130	20.70	0
13:00–14:00	90	14.33	0
14:00–15:00	20	3.18	45
15:00–16:00	80	12.74	0
16:00–16:45	30	4.78	0
Total:	**628**	**100**	**50**

Table 4.2: Analogously, the tally created on *Day 5*.

Times of day	**Number of passers-by**	**Number of passers-by (in %)**	**Not observing (in minutes)**
08:45–09:00	40	8.23	5
09:00–10:00	54	11.11	10
10:00–11:00	75	15.43	0
11:00–12:00	64	13.17	0
12:00–13:00	98	20.16	0
13:00–14:00	32	6.58	45
14:00–15:00	17	3.50	45
15:00–16:00	56	11.52	5
16:00–17:00	35	7.20	15
17:00–17:30	15	3.09	5
Total:	**486**	**100**	**130**

4.3.3 Observations: Comparing Times of Day and Types of Utilisation

The open codes *Type 1* and *Type 2* were created and were summarised in the category *Utilisation types*. While *Type 1* concerned incidents where people were interacting with the screen's surface, *Type 2* addressed situations where people became attracted by content in such a way that they focused their attention on the screen (i.e. while printing, while attending a meeting, or while stopping in front of the system). Analyses also introduced a third type of utilisation, which concerned incidents where people passed by and looked briefly at the Ambient Surface, but nevertheless they continued on their way without stopping (i.e. *Type 3*). However, it was repeatedly found during observations that people were intentionally or unintentionally looking at the screen while passing by. After *Day 1*, such incidents were only occasionally documented as their appearance was too frequent. The observation setup additionally hampered this documentation (i.e. observing people from behind). Consequently, the following largely elaborates on the two first utilisation types.

In total, 12 cases relating to *Type 1* were included. However, this sample did not correspond to the actual total number of utilisation instances. Log file analyses indicated that there were at least twelve more instances of interactions throughout this week. Due to times when the author was absent or missed such situations, these cases were not present in the field notes. Additionally, 26 instances of *Type 2* were incorporated. Figure 4.11 collates these examples and leverages the same depiction from Section 4.3.1 with reduced information regarding *Noise levels*. The illustration is enriched by presenting two more measurements relating to the two types of utilisation below each time slot. Accordingly, 9 out of 12 interaction instances occurred during the first half of a day (i.e. 08:30–13:00). Similarly, at some times of day cases of *Type 2* often occurred (e.g. 09:00–10:00 and 15:00–16:00). Nonetheless, there was an equal amount of observed passive usage in both parts of a day.

In summary, this comparison revealed that passive usage in general outnumbered active usage, whereas *Type 3* utilisations apparently accounted for the most cases. In terms of utilisation durations, 11 out of 38 incidents (*Type 1*: four cases, *Type 2*:

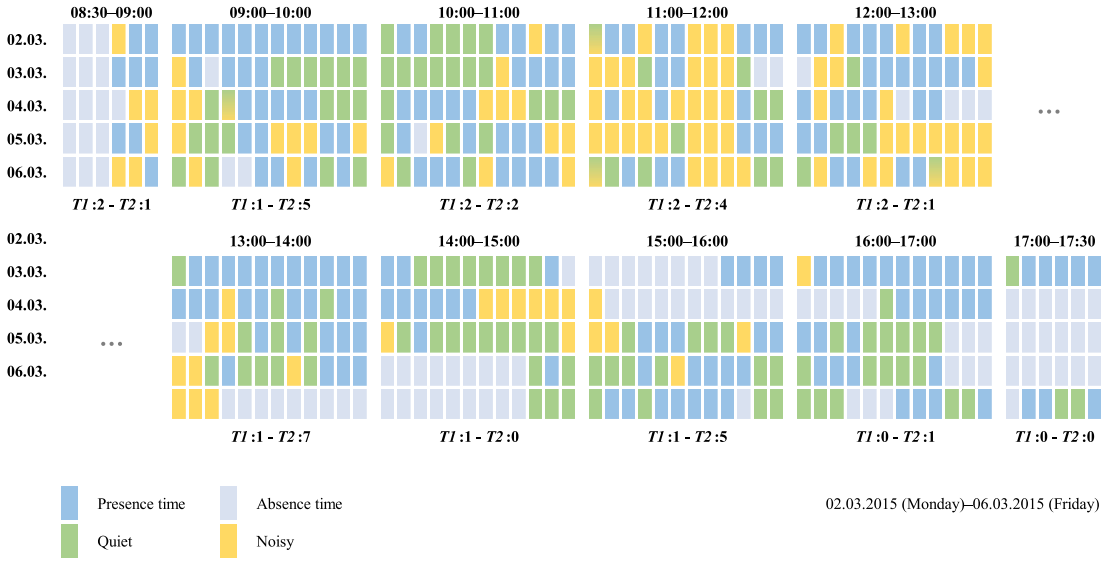


Figure 4.11: The memo from earlier, including times the author was present (dark blue), times he was absent (light blue), as well as segments indicating noisier (yellow) and quieter (green) parts of a day. Below each block there is a new figure indicating the number of utilisation instances of *Type 1* (*T1*) and of *Type 2* (*T2*).

seven cases) missed specific information due to a lack of documentation. Excluding these cases, it could be found that representatives of *Type 1* mostly lasted more than 11 seconds (five out of eight incidents). Accordingly, most *Type 2* incidents lasted less than 5 seconds (10 out of 19 cases), followed by utilisations between 5 and 10 seconds (eight cases). Generally, when comparing incidents of *Type 1* and *Type 2*, it became evident that instances of *Type 1* showed longer-lasting utilisations. While for *Type 2* the longest observed utilisation accounted for circa 20 seconds, there were three *Type 1* incidents that lasted at least 60 seconds, with one incident stretching across roughly 120 seconds. It could be observed that *Type 3* incidents were the briefest, since they lasted no longer than the time people required to walk past the Ambient Surface. Consequently, this comparison revealed that active usage principally outlasted incidents of passive utilisation, while *Type 2* utilisations could be considered to outlast *Type 3* utilisations. It was also observed that utilisation types can occur in combination; for example, when someone was intentionally walking past the system (i.e. *Type 3*) and suddenly stopped to investigate further some information (i.e. a transition into *Type 2*).

Finally, both *Type 1* (10 out of 12 cases) and *Type 2* (24 out of 26 cases) utilisations had in common that in most cases just one person was involved. This observation seemed to suggest that the system was preferably utilised to increase one's individual awareness rather than for activities such as conversations with other colleagues.

	Phase 1	*Phase 2*		
Times of day	**Interaction data (weeks 18–52)**	**Tally (*Day 4*)**	**Tally (*Day 5*)**	**Utilisation (*Type 2*)**
08:30–09:00	173	45	40	1
09:00–10:00	417	73	54	5
10:00–11:00	580	90	75	2
11:00–12:00	493	70	64	4
12:00–13:00	950	130	98	1
13:00–14:00	683	90	32	7
14:00–15:00	555	20	17	0
15:00–16:00	537	80	56	5
16:00–17:00	691	30	35	1
17:00–17:30	275	0	15	0

Figure 4.12: A comparison of interaction data from *Phase 1* with findings from observations.

4.3.4 Cross-Comparing Results from *Phase 1* and Observations

The following cross-compares the findings from observations with the results from *Phase 1*. To this end, it is related to the already defined hypotheses (i.e. except H_5 and H_6) and open questions (i.e. except Q_1, Q_4, and Q_6) to state new hypotheses. The findings from observations supported the results from *Phase 1* to some extent. As interaction data alternated, so did the noise levels and the number of passers-by. Like peaks in noise levels, the highest numbers of passers-by were observed between 12:00 and 13:00, with additional peaks in the morning and in the afternoon. Such patterns could also be observed in utilisation scenarios (i.e. particularly *Type 2* utilisations).

Figure 4.12 collates data from both research phases[4] and emphasises the relationships between segments. If a segment is higher in value than its succeeding one it is highlighted in dark blue, while opposite cases are shaded in light blue. Evidently, there were indeed times of day in which an increase in interactions equated to an increase in the numbers of passers-by (i.e. 10:00–11:00 and 12:00–13:00). This suggested that the more people that passed by the Ambient Surface, the higher the number of interactions and vice versa. This holds true for both tallies and the interaction data until 14:00. With respect to hypotheses H_2 and H_4, evidence from observations was seemingly supporting both. Potentially due to the multitude of occurring events throughout a

[4]In order to compare the results, the data from *Phase 1* was reworked. Since the documentation in *Phase 2* was organised by hour, the data from *Phase 1* was summarised accordingly. For example, the time period 09:00–10:00 contains interaction data from the half-hourly segments *09:00* and *09:30*.

day, notable decreases in the number of passers-by and in terms of passive usage (i.e. *Type 2*) could be observed (i.e. hypothesis H_4). Also, most passers-by were observed during lunch time (i.e. hypothesis H_2). Observations ultimately underlined the fact that the highest number of active and passive utilisations could be related to the event of lunch breaks. Accordingly, the following was proposed in order to frame hypotheses H_1 and H_3 in a more holistic manner:

- H_8: The Ambient Surface is notably utilised beyond lunch time, depending on the number of passers-by, which leads to correspondent increases and decreases in utilisations throughout a day.

Hypotheses H_1 and H_3 solely suggest that interaction data notably correlates to the events of arriving at (i.e. hypothesis H_1) and leaving from (i.e. hypothesis H_3) work. However, there was apparently a general connection between the number of passers-by and resulting utilisations. The reasons to pass by were multitudinous, which simultaneously provided answers to question Q_2. People were observed, for example, fetching a beverage from the kitchen. These results also suggest that the general installation setup played a crucial role. In light of questions Q_3 and Q_5, it was found on *Day 1* that people typically looked at the screen while passing by. It was also repeatedly observed that people were discontinuing their intended route and stopped for some time in front of the system (i.e. *Type 3* utilisation transcended to that of *Type 2*). The following concludes this cross-comparison by listing supplementary hypotheses:

- H_9: Individual use outnumbers group usage.
- H_{10}: The Ambient Surface is most notably leveraged to increase one's individual awareness of information.
- H_{11}: Active usage outlasts its passive counterpart.
- H_{12}: Passive usage outnumbers its active counterpart.
- H_{13}: *Type 3* utilisation incidents outnumber those of *Type 2*.
- H_{14}: *Type 2* utilisation incidents outlast those of *Type 3*.
- H_{15}: Types of utilisation may occur in combination.

4.3.5 Group Interview: Comparing Interviewee Statements

At this point of the analysis it became apparent what Glaser (1978, p. 57) refers to with the question: "What is this data a study of?" The following elaborates on the two categories of *Information visibility* and *Spontaneous utilisation* (i.e. the emergent core category) that were repeatedly indicated during the interview and happened to constitute the underlying conceptual pillows of the emergent theory. Subsequent to their introduction, it is described how both categories seemingly relate to one another. As names are anonymised, the following synonyms are used below: *Mr Vega* and *Mr Blue* (Scrum Masters); *Ms Brown*, *Ms Green*, and *Mr Hanzo* (software developers); and *Mr Pink* (head of department).

The Category of *Information visibility*

Numerous statements throughout the interview related directly or indirectly to topics surrounding information visibility. That included negative and positive impacting factors, but also different domains such as visibility on a team, individual, and general level.

Overall, the amount of simultaneously displayed information in combination with the fact that only one display was deployed was consistently perceived as negative by interviewees. Following *Mr Vega*, teams reportedly had to compete for the available space (e.g. the *Jira* view). In terms of positive impacting factors, *Mr Blue* stated that the continuous evolution of the Ambient Surface was beneficial. Furthermore, the way of presenting information in such a format was perceived by *Mr Vega* as positive. Also, the selected location was positively acknowledged by *Mr Blue* and *Mr Pink*, since supposedly every staff member had to pass by the system.

However, people largely referred to general topics. For example, *Ms Brown* appreciated the fact that the *Jira* view assisted in investigating individual work tasks. Generally, *Mr Blue* thought it was relevant to display live information. *Mr Pink* and *Ms Brown* appreciated the visualisation of latest information such as messages from the architecture board in the *Confluence* view. *Ms Brown* also used the phrase "news ticker" in this context. *Mr Vega* stressed the issue that the processing of information

was very rapid, since the system combined a variety of content on one screen. He also said that the somewhat new way of presenting information helped him in finding something in the first place and becoming aware of unknown content. This random exploration of information was also supported by *Ms Brown* and *Mr Blue* throughout the interview. The literature refers to this phenomenon as the *serendipity effect* (Ott and Koch, 2012). Principally, *Mr Blue* believed that information transparency entails implications such as it happened in the past, when someone was asking him about displayed content. However, he underlined this issue as beneficial, which was also supported by *Mr Pink*. Contrary to *Mr Hanzo*, *Ms Brown*, *Mr Vega*, and *Ms Green* saw no effects of better team awareness due to readily presented content. They argued that formats such as the Scrum of Scrums meeting are better suited to promote team awareness, while *Mr Blue* rather concurred with *Mr Hanzo* in this regard.

Ms Green added that her team was more critical towards the Ambient Surface, since the included information was already available elsewhere and often the displayed information was not relevant. It is worth mentioning, however, that *Mr Pink* stated earlier in the interview that people typically tend to forget information when it is out of sight.

In summary, feedback regarding information visibility topics seemingly put forth answers to why or why not staff members utilised the Ambient Surface.

The Emergent Core Category of *Spontaneous utilisation*

Aggregating feedback in a category called *Spontaneous utilisation* seemed to bring up participants' main concern in resolving how to describe their usage. Interviewees shared the belief that the main driver for utilisations are spontaneous and unplanned situations while individuals or groups of individuals are passing by. There was generally no supporting evidence for deliberate usage. For instance, *Ms Brown* explained that software developers apparently did not utilise the system on purpose. *Mr Vega* further added that he can hardly imagine a situation in which it would make sense to use the system other than by accident. Similarly, *Mr Blue* elaborated: "However, not regularly, but actually more in spontaneous occasions when I walk past it." *Mr Pink* supported this statement, as he described his usage behaviour similarly.

Ad-hoc usage comes in the form of the mentioned utilisation types, while utilisation by itself is highly dependent on individual preferences as *Mr Pink* stated. *Mr Blue*, for example, said that he used the system to an equivalent amount actively and passively. *Mr Hanzo* explained while talking about his team that passive usage outnumbered interactions, which also supported observational findings. Furthermore, interviewees observed individuals and groups of individuals utilising the Ambient Surface. While *Mr Blue* said that in roughly two-thirds of the cases, people were using the system alone, *Ms Brown* stated that there was an equal amount of individual and group situations. *Mr Blue* also added that times of day played an important role in his belief, while during lunch time, he observed more groups of people. However, both *Mr Hanzo* and *Ms Brown* concurred that the deployment location was typically very crowded and a place where people frequently exchanged information. This was also supported by a comment from *Mr Blue* earlier in the interview where he said that he regularly observed groups of individuals in front of the Ambient Surface discussing formal and informal topics (e.g. making fun of the burn down chart of another team).

It also became somewhat apparent what potential implications of utilisation could look like, since incidents of subsequent direct communication were reportedly provoked. Both *Mr Blue* and *Mr Vega* commented on incidents where they were approached by colleagues because of displayed content. *Mr Vega* also added that he had often proactively engaged with colleagues due to discovered information to ask further questions.

In summary, it could be concluded that patterns observed in interaction data and during observations likely occurred on account of random and spontaneous incidents. At this stage of research, the apparent core theme of the emergent theory took shape.

The Link Between Both Categories

At some point during the analysis, it was realised that there is a link between *Information visibility* and *Spontaneous utilisation*. Here, the relevance of information played an important role, since relevance seemingly depended strongly on individual roles. For instance, while software developers emphasised they were interested in content shown in the *Jenkins* view, the head of department and both Scrum Masters highlighted the importance of content visualised in the *Team Charts* view. Evidently, the visibility

of relevant information is a strong precondition for ad-hoc utilisations, since people supposedly tended to simply pass by the system if the presented information was not relevant to them. *Mr Pink* corroborates this issue by saying that "when there are things which you are not interested in, then you pass by." People were supposedly also passing by the system without further consideration when they were in a rush or a hurry. Furthermore, people seemingly evaluated content in the matter of a split second while passing by. This is supported by *Mr Hanzo*, who commented that one is typically looking at the screen out of sheer curiosity while walking past it. The total number of passers-by was affected by several impacting factors, as was also found earlier during observations. While, for instance, meetings and arriving at work reportedly had a positive effect on the total number of passers-by, workloads (e.g. Sprint end) and trainings potentially accounted for the opposite. Whilst referring to latent patterns from *Phase 1*, interviewees related incidents to the events of arriving at work (i.e. 08:00–09:00), fetching beverages (i.e. 10:00–10:30), attending meetings (i.e. around 11:00), and lunch time (cf. hypotheses H_1–H_3).

In summary, to account for this emergent linkage between both categories, a further category labelled *Passing-by* was created.

4.3.6 Cross-Comparing Results from *Phase 1*, Observations, and the Group Interview

Overall, the contributions from this cross-comparison were more on a conceptual level than a theoretical one. Up to this point, *Phase 2* highlighted the building blocks of the emergent theory in the form of the three categories mentioned earlier. Fundamentally, findings from the group interview contributed the main cause of utilisation (i.e. random and spontaneous incidents) in which people engaged with the Ambient Surface. Generally, the interview data provided fewer new insights in terms of the covered latent patterns (i.e. hypotheses H_1–H_4, H_{10}, and question Q_2). However, it indicated the first insights in explaining why (or why not) and how utilisation took place (e.g. in light of passive usage relating to question Q_3) as well as shedding further light on the topics of display blindness (i.e. question Q_5) and of contribution factors (i.e. hypothesis H_7 and question Q_1). It was found both in observations and the group interview that

people tended to look at the screen while passing by. Threats stemming from display blindness seemingly still showed no strong predominance as people reported to typically look at the screen while walking past it. Furthermore, staff members apparently processed displayed content in such a way that they could decide whether to engage further. Additionally, the most important contribution factors were awareness of somewhat relevant information and the fact that people were able to randomly discover information. Contrary to observations, the group interview additionally enabled to draw first rather profound conclusions with respect to utilisation implications. For instance, people reportedly engaged colleagues in direct communication due to visualised content on the screen.

In summary, the following theoretical codes were proposed based on the group interview:

- H_{16}: Times of day affect the ratio of passers-by in terms of individual users and group usage.
- H_{17}: Individual preferences affect incidents of spontaneous utilisation.

4.3.7 Cross-Comparing Results from *Phase 1*, Observations, the Group Interview, and the Online Survey

The last cross-comparison of *Phase 2* is now presented. A focus was placed on the categories of *Information visibility*, *Spontaneous utilisation*, and *Passing-by*. With this decision, these codes became selective codes as they were deemed more important than others (Muller and Kogan, 2012). MAXQDA was reused, but also statistical summaries which were auto-generated by the online survey tool were utilised. The reader is reminded that now two Ambient Surfaces were deployed at Werum. Of the 35 survey respondents, 28 people reported to utilise or had utilised the systems. In instances, however, respondents did not provide answers to every survey item (i.e. $n < 28$). Overall, the survey contributed some new conceptual and theoretical codes.

The Category of *Information visibility*

There were some aspects that characterised this category more thoroughly. For instance, one of the noted Ambient Surfaces' strengths was that people could see what was happening in the department (60.7% of 28 respondents). Evidently, the Ambient Surfaces also positively affect the visibility of (76.9% of 26 respondents) and simultaneously ease access to information (71.4% of 28 respondents). Almost one-third of the 28 respondents said that the displayed information was insufficient and 25% felt that important information was not displayed. A further 10.7% of respondents said both that there was too much information and that the design of the user interface was not appealing. Also, 7.1% said that daily work routines were not meaningfully fostered.

Apparently, the systems promote better inter-team awareness (n = 26, standard deviation [SD] = 0.98, mean = 2.62, median = 2.00) than intra-team awareness (n = 26, SD = 1.48, mean = 3.54, median = 4.00). People repeatedly responded that they were already aware of their team's tasks. Additionally, it became apparent that the systems somewhat fostered the creation of an awareness of unknown information, which supported the aspect of randomly finding relevant information (n = 26, SD = 1.16, mean = 2.69, median = 2.00). However, most respondents felt that their way of acquiring information has not changed (64.3% of 28 respondents). Awareness-related findings led to the following theoretical code:

- H_{18}: The creation of inter-team awareness outweighs the creation of intra-team awareness.

Additionally, findings underlined that information visibility also concerns personnel external to the department. Reportedly, access to department-internal information was made profoundly easier for such personnel.

The Core Category of *Spontaneous utilisation*

Initially, issues are summarised that concerned the core category in general. As many as 46.4% of the 28 users said that they utilised the systems daily and 50% reported a weekly usage behaviour. People's main motivation for utilisations was to get a first, rough overview (100% of 28 respondents). Overall, data showed that most respondents

concurred with the current state of analysis that usage is most suitably described as spontaneous (82.1% of 28 respondents), while the Ambient Surfaces were reportedly mostly used prior to, during, or after lunch time (82.1% of 28 respondents), followed by situations when fetching a beverage (67.9%). Other incidents were prior to or after a meeting (28.6%); while printing (28.6%), prior to, during, or after breakfast (25%); and during a meeting in front of the systems (25%). These illustrations underlined, for instance, utilisation patterns such as described in hypotheses H_1–H_4.

The data collected indicated how and to what extent communication occurred (i.e. utilisation implications). Of the 28 respondents, 92.9% highlighted that they observed discussions in front of the systems, which 26 people characterised as spontaneous (92.3%), informal (50%), and formal (42.3%). In most cases, two people were involved in these gatherings (80.8% of 26 respondents), followed by three people (69.2%), four people (46.2%), five people (34.6%), and more (19.2%). Furthermore, 67.9% of the 28 respondents said that they initiated communication and 89.3% participated in discussions in front of the Ambient Surfaces. A notable number of respondents (64.3%) had been engaged by team colleagues in the past due to information visible on the screens, while 53.6% approached colleagues from other teams. Similarly, 28 people stated that they were slightly more often approached by teammates (42.9%) than by colleagues from another team (35.7%). The relevance of communication is exemplified by one comment from a respondent: "Having information about all teams simultaneously at one location often encourages spontaneous discussions among colleagues. This fosters the exchange or informs many about the work of others." Interestingly, one respondent stressed the fact that he or she was regularly observing that when someone was standing in front of the systems, others were getting attracted. The literature refers to this social advent as the *honey-pot effect* (Brignull and Rogers, 2003).

Individuals' information-gathering processes were also affected. For instance, one respondent said that the Ambient Surfaces reminded him or her to subsequently investigate information further. Additionally, someone reported that he or she investigated team charts solely on the Ambient Surfaces in 90% of the cases. It was also commented by a person that he or she exclusively consumed certain information on the Ambient Surfaces. Also, there was evidence underlining the passive value as people were not

required to interact with the screens to unveil information. It was further noted that throughout coffee breaks, workflows in front of a desktop computer were not interrupted. When people were not at their desks, the Ambient Surfaces were supposedly the only way of acquiring information.

Seven respondents raised issues that prevented them from using the systems. For example, people preferred other ways of acquiring information or were not part of the department. Overall, the presented results translated to the following theoretical codes:

- H_{19}: Personal information work preferences affect the general attitude towards the Ambient Surfaces while passing by.
- H_{20}: The creation of subsequent intra-team communication outweighs the creation of subsequent inter-team communication.
- H_{21}: People standing in front of the Ambient Surfaces attract other potential users.

The Category of *Passing-by*

A comparison of respondent feedback corroborated the criticality of the process of passing-by. For example, when respondents were asked for lasting impressions of the deployment, eight distinct comments were made in this regard (e.g. "The good overview. Everything at a glance and virtually while passing by."). When asked for the reasons why the Ambient Surfaces increased information visibility, a total of 12 comments were provided (e.g. "Because on the way to the kitchen they are visible as I pass by without having to do anything."). A similar picture stemmed from the investigation of answers to the question of how access to information was made easier where seven notes were given (e.g. "Information can be retrieved during coffee breaks meaning the normal workflow on the PC is less disturbed."). A further five comments were stated in the context of the question of individual changes in the acquirement of information (e.g. "I get information that can be seen on the Ambient Surface system by walking past it and no longer look for it in the workplace."). Although the online survey unveiled first indications of deliberate usage, it largely linked usage to the process of passing-by.

4.3.8 Conclusion

Phase 2 represented a further concluding conceptual and theoretical stepping stone towards a comprehensive understanding of the Ambient Surfaces' long-term utilisation.

Addressing the Research Phase Question

Phase 2 contributed substantial conceptual and theoretical insights. In total, it proposed 14 additional theoretical codes (i.e. hypotheses H_8–H_{21}). This contribution arose from answers to how and why the systems were utilised. It was learned that utilisation is best described in the form of the core category of *Spontaneous utilisation* which, in turn, is informed by the categories of *Information visibility* and *Passing-by*. *Phase 2* revealed that people typically did not utilise the systems deliberately; they tended to engage passively or actively when they were walking past the Ambient Surfaces by accident. The inherent process of evaluating information relevance was crucial in these incidents as people reportedly simply passed by when the presented information was perceived irrelevant.

Emergent Questions

Phase 2 investigated most of the emergent questions from *Phase 1*. This excluded questions Q_4 and Q_6 as it felt less relevant to follow up on them at this stage of research. Questions that were only partly or hardly addressable by considering data from *Phase 2* and simultaneously represented questions for further investigations were:

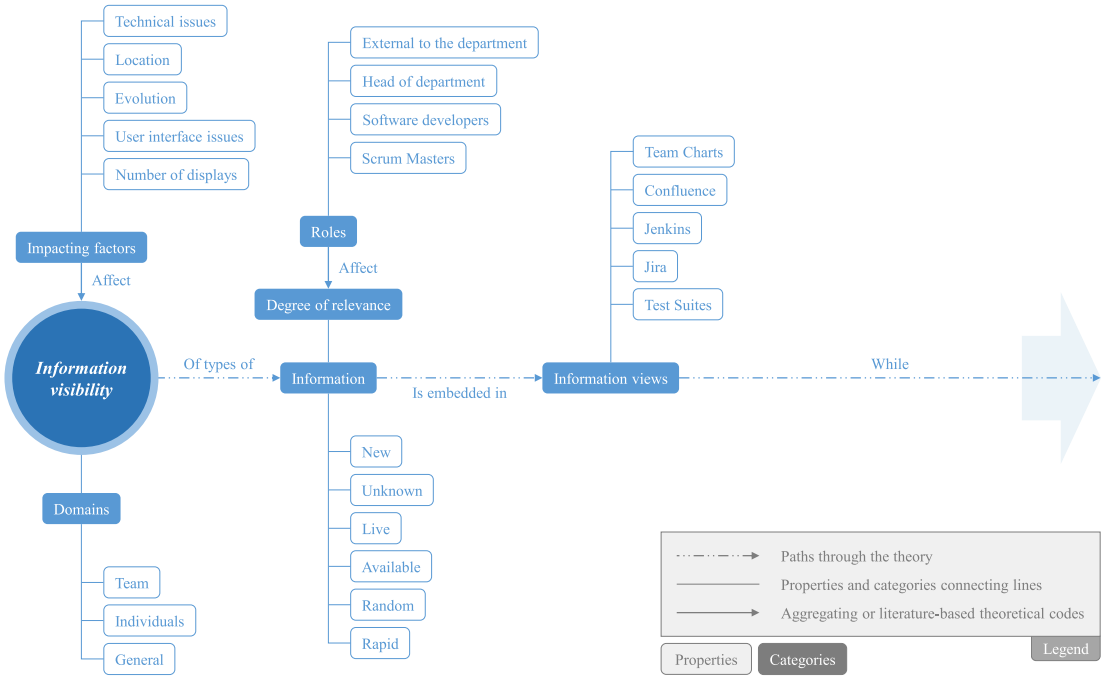
- Q_7: How do the identified three types of utilisation occur in combination?
- Q_8: How does the result of processing information relevance affect subsequent activities?
- Q_9: What characteristics show candidates of deliberate utilisation?
- Q_{10}: How are the varying information views utilised?
- Q_{11}: How is individual information work affected?

- Q_{12}: How frequently do incidents of direct communication occur subsequently to spontaneous utilisation incidents?
- Q_{13}: What is the content of subsequent indirect communication incidents?
- Q_{14}: How distinctive is individual usage when considering a large number of users?

Pictorial Model of the Emergent Theory

Figures 4.13a, 4.13b, and 4.13c conceptually collate the evidence presented in *Phase 2*. The same rules described in *Phase 1* were applied here. Similarly, certain liberties were taken in designing these illustrations as, again, one is not looking for conceptual coverage (Glaser, 1998). However, the illustrations introduce a fourth kind of connecting lines—dotted and dashed arrows that indicate the varying paths through the proposed theory (i.e. from left to right). Overall, when sorting and writing up findings in *Phase 2*, it was aimed at finding a reasonable writing-illustration dosage to outline the emergent theory. The illustrations embody a major revision of the pictorial model used in *Phase 1* (cf. Figure 4.9). For example, details relating to the *Novelty effect* were removed to reduce the complexity (i.e. hypothesis H_6), and the category *Contribution factors* (i.e. including hypothesis H_7) transcended into a sub-category of *Spontaneous utilisation* named *Motivation*. Finally, it is noted that some elements in the depictions are denoted according to the feedback as this sometimes may seem confusing (e.g. the properties *New* and *Unknown* for the category *Information*). To describe the emergent theory, illustrations are explained from left to right.

Information visibility is affected by different reported *Impacting factors*. While, for instance, the continuous *Evolution* of the system helped Werum (e.g. adding a new information view), *User interface issues* such as the amount of simultaneously displayed information was perceived as challenging. People were also referring to visibility in different contexts, denoted as *Domains*. While some talked about *Team*-related issues (e.g. *Team Charts* view), others made statements regarding *Individual* (e.g. Jira view) and more *General* (e.g. visibility of available information) aspects. The Ambient Surfaces enable visibility of different types of *Information*. Interviewees related to

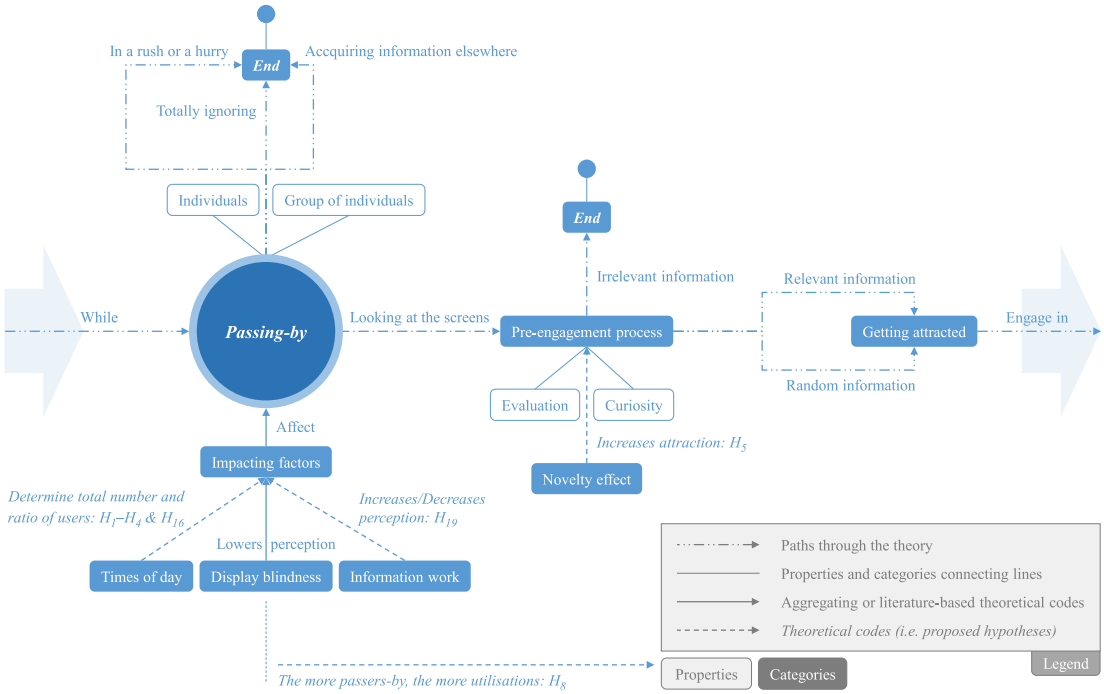


(a) The category of *Information visibility*.

Figure 4.13: A visualisation of the emergent theory in *Phase 2*, including its three key buildings blocks *Information visibility*, *Passing-by*, and *Spontaneous utilisation*.

information in several ways such as *New*, *Live*, and *Random*. Information can further have a *Degree of relevance* that is in turn affected by *Roles* people embody. For instance, while *Software developers* lean towards information concerning their daily work (e.g. *Jenkins* view), *Scrum Masters* and the *Head of department* stressed their interest in content indicating an overview (e.g. *Team Charts* view). *Information* is generally displayed in a set of *Information views* (e.g. *Confluence* view).

The content is presented to *Individuals* and *Groups of individuals* while they are passing by the Ambient Surfaces. Typically, when passers-by are in a rush or a hurry, they supposedly just walk past the systems without any further consideration. The process of passing-by is affected by three apparent *Impacting factors*. Firstly, both the total number of passers-by and the ratio of individuals and groups of individuals depend on what is referred to as *Times of day*. While, for instance, during lunch time most passers-by were observed, the numbers varied for the rest of the day. Secondly, *Display blindness* lowers the perception of the systems and potentially leads to people totally

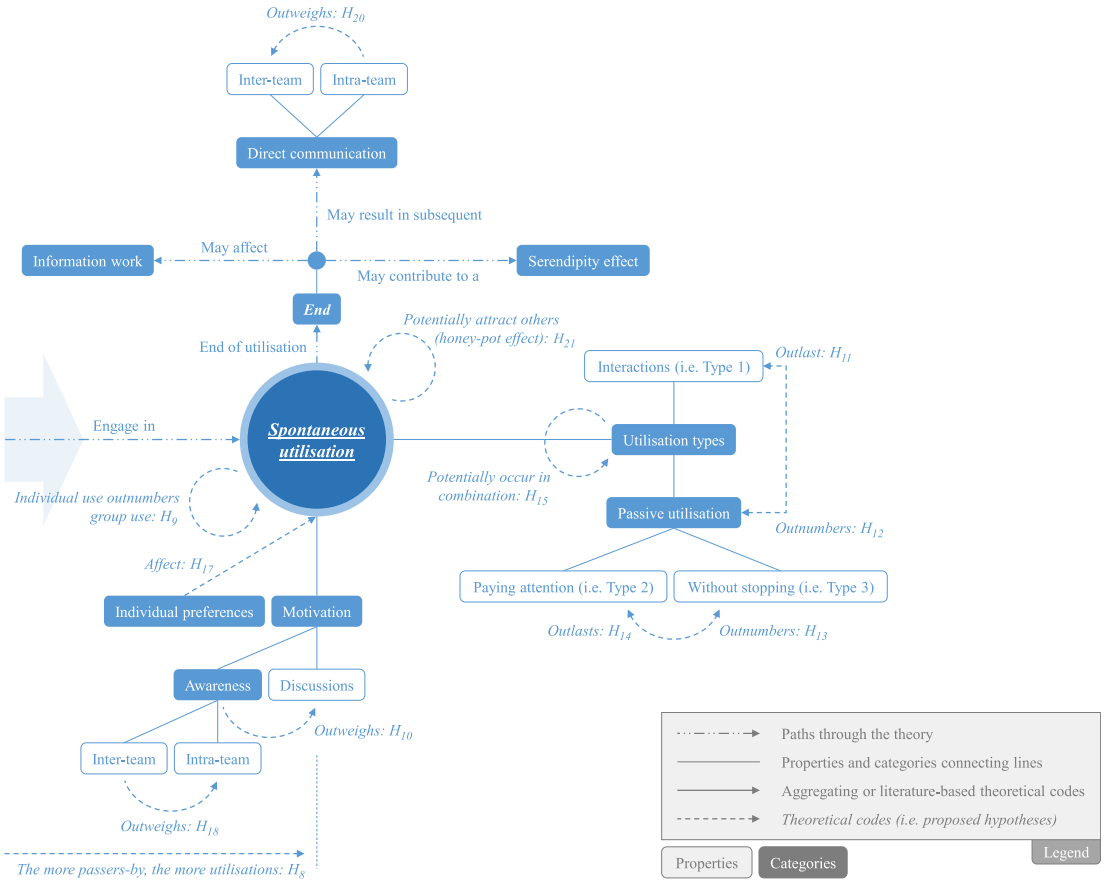


(b) The category of *Passing-by*.

Figure 4.13: Continued.

ignoring them while passing by. Lastly, how people conduct their *Information work* also affects perception as some people preferably acquired information elsewhere and others entirely on the Ambient Surfaces. When people were then looking at the screens, they were seemingly involved in a procedure that is denoted as *Pre-engagement process*. People were driven by an *Evaluation* of information relevance or by *Curiosity*. While people reportedly walk past the system when irrelevant information is displayed, they are attracted in cases of relevant information and when they are curious. A decision to further engage is seemingly concluded in a split second. The *Novelty effect* affects this cognitive procedure as it potentially increases the attraction towards the Ambient Surfaces.

If people were attracted, they engaged in *Spontaneous utilisation*. Fundamentally, utilisation is affected by *Individual preferences* (e.g. active or passive usage) and individual use seemingly outnumbers the cases of group usage. People standing in front of the display potentially attract others. The motivation to engage in utilisations is twofold. Firstly, people were foremost referring to aspects relating to *Awareness* such as team awareness. Here it could be found that the Ambient Surfaces more likely promote



(c) The core category of *Spontaneous utilisation*.

Figure 4.13: Continued.

Inter-team awareness. Secondly, people leverage the systems to also be involved more frequently in *Discussions* with colleagues. However, the relevance of awareness seemingly outweighs the of discussions. *Spontaneous utilisation* comes in the form of three types (i.e. *Type 1*, *Type 2*, and *Type 3*). While *Interactions* typically outlast *Passive utilisation*, the latter outnumbers the former. While *Type 3* incidents potentially account for most incidents, they are simultaneously the briefest in nature. All three types of utilisation may also occur in combination. Furthermore, implications of ad-hoc utilisations could be identified. Respondents reported that they proactively confronted colleagues in subsequent *Direct communication* due to displayed information and were simultaneously confronted because of visualised content. Interestingly, communication and awareness findings were contradictory in the sense that apparently predominantly *Intra-team* communication was encouraged. Additionally, there were indicators that exemplified subsequent changes in people's way of conducting *Information work*. For

instance, it was referred to the process of deriving subsequent actions to acquire more information. Finally, it was apparent that people also discovered relevant information by accident (i.e. the *Serendipity effect*).

4.4 *Phase 3*: Long-Term Interaction Data

Initially, the relevant view event log file was revised to remove unnecessary lines. Data relatable to the prevalence of the novelty effect was also removed. These steps reduced the total number of view events down to 754,579 (see Figure 4.14). However, the analysis was not restricted to certain events (cf. *Phase 1*). In *Phase 3*, it was intended to relate usage to the individual information views. For statistical analyses, a confidence interval of 95% (i.e. $p = .05$) was defined to state statistical significance. The sample size for all tests was n = 27 (analogously to the 27 time segments *07:00*, ..., *20:00*).

4.4.1 Comparing Descriptive Statistics of Long-Term View Events Data

View events and their percentage-wise occurrences throughout the considered years were initially focused on. Figure 4.14 illustrates the corresponding data on a year-to-year and system-to-system (respectively labelled *System 1* and *System 2*) basis. Percentage figures in this depiction do not always add up to a total of 100% as some events relating to the features *Meeting Reminder* and *Sharing* were not considered. Furthermore, the illustration includes the category *Main window*. This category is listed to indicate the amount of interactions which do not account for views (e.g. navigation gestures). Additionally, icons (e.g. ↔) indicate the necessity and kind of scrolling gestures in the corresponding information views.

Evidently, the varying revisions of the Ambient Surfaces' user interface resulted in substantial differences in the total number of view events. This fact gets exemplified when comparing the total number of events prior to Week 33 in 2015 with the rest of the samples (e.g. *System 1* in 2015 > Week 33). In that time period, the user interface was the widest in width hence people were sometimes required to scroll intensively to unveil or to curiously discover information. After Week 33 in 2015, view event percentage

	2014		2015						2016				2017			
Information views	**Weeks 18–52**		**< Week 33**		***System 1* (> Week 33)**		***System 2***		***System 1***		***System 2***		***System 1***		***System 2***	
Bug Survey	–	–	–	–	–	–	–	–	–	–	–	–	12.00%	–	–	–
GoCD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	27.72%	↕●
Jira (aggregated)	17.01%	↕	4.54%	↕	–	–	–	–	–	–	–	–	–	–	–	–
Confluence	15.44%	↔↕	20.49%	↔↕	87.82%	↔↕	–	–	35.43%	↔↕	–	–	30.95%	↕	–	–
Team Charts	15.84%	↕●	12.14%	↕●	0.31%	↕●	–	–	33.64%	↕●	–	–	43.56%	↕	–	–
Test Suites	–	–	3.29%	↔↕●	–	–	14.69%	↕●	–	–	21.87%	↔↕●	–	–	10.21%	↕●
Jenkins (aggregated)	8.26%	↕●	7.01%	↕●	–	–	29.08%	↕●	–	–	52.70%	↕●	–	–	12.94%	↕●
Main window	43.39%	↔	52.50%	↔	11.87%	●	56.23%	↔●	30.42%	↔●	20.17%	●	13.46%	↔	47.83%	↔
Total:	99.94%		99.97%		100.00%		100.00%		99.49%		94.74%		99.97%		98.70%	
Number of events:	164,850		186,512		41,599		15,948		125,968		29,214		119,871		70,617	

↔ = Horizontal scrolling required ↕ = Vertical scrolling required ● = No scrolling required

Figure 4.14: Information views and their percentage-wise occurrences on a year-to-year as well as system-to-system basis.

figures from the views *Confluence*, *Team Charts* (i.e. except in 2015), *Jenkins*, and *Test Suites* were comparably higher in values. As a consequence, one could argue that scrolling gestures related to search efforts affected measurements to a lesser or greater extent. Apparently, a similar impact on measurements can be observed in terms of a view's complexity. For example, the *Confluence* view (long articles) and the *Team Charts* view (visual diagrams) substantially varied in the total numbers of interactions in 2015 starting in Week 34. This aspect corroborated the issue that differences in utilisation patterns may also be related to the characteristics of a user interface.

Attention is now drawn to Figure 4.15[5]. Similarly to cross-tabulations in *Phase 1*, time slots are presented in a tabular overview. These time slots are related to information views which are abbreviated accordingly in the depiction. In addition, the number of indicators—with respect to both a specific time of day slot (i.e. rows) as well as a particular year and system (i.e. columns)—are collated in a tabular overview. Data is initially discussed in relation to the latter case (i.e. tabular overview at the bottom). Certain views dominated usage throughout an entire day. For instance, in 2015 (i.e. *System 1* subsequent to Week 33) the *Confluence* view dominated all 27 time slots in terms of the total number of view events. However, at times, only a small number of scrolling gestures were required in the *Team Charts* view. Similar strong dominant patterns are observable for the *Jenkins* view on *System 2* in 2016, the *Team Charts* view in 2017 (i.e. *System 1*), and the *GoCD* view in 2017 (i.e. *System 2*). The department's

[5]The *Bug Survey* view is not included in this depiction as, at no time, did this view account for most view events in a given time slot.

	2014	2015			2016		2017	
	Weeks 18–52	**< Week 33**	***System 1* (> Week 33)**	***System 2***	***System 1***	***System 2***	***System 1***	***System 2***
07:00	JI	JE	CO	JE	–	JE	CO	JE
07:30	TC	CO	CO	TS	–	–	TC	TS
08:00	JE	CO	CO	JE	CO	JE	TC	GO
08:30	TC	CO	CO	JE	CO	JE	TC	GO
09:00	JE	CO	CO	JE	TC	JE	TC	GO
09:30	CO	CO	CO	TS	CO	JE	TC	GO
10:00	TC	CO	CO	TS	TC	JE	TC	GO
10:30	CO	JI	CO	TS	TC	JE	TC	GO
11:00	TC	CO	CO	JE	CO	JE	TC	GO
11:30	TC	TC	CO	TS	TC	JE	TC	GO
12:00	CO	JE	CO	JE	CO	TS	TC	JE
12:30	JI	JI	CO	JE	TC	JE	TC	JE
13:00	JI	CO	CO	JE	TC	JE	TC	GO
13:30	CO	CO	CO	TS	CO	JE	CO	GO
14:00	TC	CO	CO	JE	TC	JE	CO	GO
14:30	JI	CO	CO	JE	CO	JE	TC	GO
15:00	CO	CO	CO	JE	CO	JE	TC	GO
15:30	CO	CO	CO	JE	CO	JE	CO	GO
16:00	CO	CO	CO	JE	CO	JE	TC	GO
16:30	JI	CO	CO	JE	CO	JE	CO	GO
17:00	TC	TC	CO	TS	TC	JE	TC	GO
17:30	TC	CO	CO	JE	CO	TS	CO	GO
18:00	TC	CO	CO	JE	CO	JE	TC	GO
18:30	TC	CO	CO	JE	TC	JE	TC	JE
19:00	JE	CO	CO	JE	CO	JE	CO	GO
19:30	JE	JE/TC/TS	CO	JE	CO	JE	CO	TS
20:00	JE	JE	CO	TS	TC	JE	–	JE

	JI (max. 2)	**TC (max. 5)**	**JE (max. 5)**	**CO (max. 5)**	**TS (max. 4)**	**GO (max. 1)**
	1	0	4	2	0	0
	0	2	0	2	2	0
	0	1	3	3	0	1
	0	2	2	3	0	1
	0	2	3	2	0	1
	0	1	1	4	1	1
	0	3	1	2	1	1
	1	2	1	2	1	1
	0	2	2	3	0	1
	0	4	1	1	1	1
	0	1	3	3	1	0
	2	2	3	1	0	0
	1	2	2	2	0	1
	0	0	1	5	1	1
	0	2	2	3	0	1
	1	1	2	3	0	1
	0	1	2	4	0	1
	0	0	2	5	0	1
	0	1	2	4	0	1
	1	0	2	4	0	1
	0	4	1	1	1	1
	0	1	1	4	1	1
	0	2	2	3	0	1
	0	3	3	2	0	0
	0	0	3	4	0	1
	0	1	4	3	2	0
	0	1	4	1	1	0
Total:	**7**	**41**	**57**	**76**	**13**	**20**
Total (in %):	**12.96**	**30.37**	**42.22**	**56.30**	**12.04**	**74.07**

JI	5	2	–	–	–	–	–	–
TC	10	3	0	–	10	–	18	–
JE	5	4	–	19	–	24	–	5
CO	7	19	27	–	15	–	8	–
TS	–	1	–	8	–	2	–	2
GO	–	–	–	–	–	–	–	20
Total:	**27**	**29 (27)**	**27**	**27**	**25**	**26**	**26**	**27**

JI = *Jira* view
TC = *Team Charts* view
JE = *Jenkins* view
CO = *Confluence* view
TS = *Test Suites* view
GO = *GoCD* view

Figure 4.15: The most utilised information views for a particular time of day (table on the right) and system (table at the bottom), while blue highlights indicate maximum values.

shift from Jenkins to GoCD is also reflected in the figure when comparing *System 2* in 2016 and 2017. Seemingly, the relevance of content changed during that time.

In what follows, exemplary incidents are presented where an information view indicates its highest dominance by horizontally counting its occurrence for a specific time of day (i.e. the tabular overview on the right). For example, the *Confluence* view could potentially have shown a maximum of five cases as it was available from its initial deployment in 2014, in 2015 (prior to Week 33), as well as in 2015, 2016, and 2017 on *System 1*. Usage of the *Confluence* view indicated such dominances in interaction at 13:30 and 15:30. Another example is the *Team Charts* view, which could also indicate a maximum of five incidents as it was also deployed in 2014 alongside the *Confluence* view. This view showed a strong dominance at 11:30 (when the Scrum of Scrums meeting commenced) and 17:00. Apparently, content relevance also changed considering different times of day.

In conclusion, the preceding allowed the assumption that interactions relating to both the process of searching for desired information and of curiously exploring content may play a considerable role. Fundamentally, analyses posed questions surrounding user interface characteristics as they demanded somewhat distinct ways of interaction. It was likely that past revisions of the user interface affected the utilisation figures. The following hypotheses were put forth:

- H_{22}: The design complexity of information views affects the total number of utilisations (i.e. *Type 1*).
- H_{23}: The efforts to unveil an information view affect the total number of utilisations (i.e. *Type 1*).
- H_{24}: Utilisation behaviour changes as the relevance of content changes.
- H_{25}: Content relevance depends on a particular time of day.

4.4.2 Statistically Comparing Long-Term Interaction Data

It was assumed that the index comparison conducted in *Phase 1* revealed *authentic*[6] interaction behaviour. Similarly, it was hypothesised that such behaviour was also prevalent in interaction data from subsequent years, meaning that some of the hypotheses already proposed in *Phase 1* would likely also apply to other time periods. It was believed that latent patterns identified in *Phase 1* did not markedly deviate from those in subsequent years. The intended goal of the following analyses was to investigate the stretch of this assumption.

There were certain known impacting factors that required further attention in such a consideration. The preceding analyses regarding view events played a crucial role in this process as they suggested differences in usage due to, for example, content sizes. Generally, both systems underwent minor (e.g. updating a logo) and major (e.g. new information views) revisions. Scrum teams were also reorganised in Week 14 of 2016. Additionally, all of the staff were relocated to a newly constructed building in Week 6 of 2017. From then on, all staff members from the entire company's headquarters became potential users due to the presence of a canteen in the building. Further issues also emerged from the fact that two Ambient Surfaces were deployed after Week 32 in 2015. Although both systems were continuously situated together, an additional monitor and the separation of content played another important role to consider.

Defining Null Hypothesis H_{test}

The issue at hand became pinpointing statistical analyses to interaction data stemming from similar conditions. It was therefore decided to focus the efforts in the second part of *Phase 3* on a specific time period. This time period included interaction data from 2014 (i.e. since Week 18) and 2015 (i.e. prior to the installation of the second system in Week 33) as during this time period the first system neither underwent substantial changes nor was it relocated nor were teams reorganised. Considering the aforementioned, it was hypothesised that interactions during this time frame were not different

[6]The term authentic is intended to link to unbiased interactions with the Ambient Surfaces beyond effects such as the novelty effect. With that the myriads of situations in which people were utilising the systems are referred to.

	2014	2015			2016		2017			
	Weeks 18–52	< Week 33	*System 1* (> Week 33)	*System 2*	*System 1*	*System 2*	*System 1*	*System 2*	Total:	Total (in %):
07:00	9	14	20	9	0	12	0	2	66	0.18%
07:30	70	57	37	15	0	1	9	62	251	0.70%
08:00	43	106	53	22	57	15	94	121	511	1.42%
08:30	173	213	54	151	85	75	202	125	1,078	3.00%
09:00	254	348	51	96	188	123	216	252	1,528	4.25%
09:30	163	138	100	24	235	66	175	158	1,059	2.95%
10:00	306	236	92	128	256	119	180	299	1,616	4.50%
10:30	274	246	63	47	316	92	240	174	1,452	4.04%
11:00	268	483	85	120	150	81	252	268	1,707	4.75%
11:30	225	505	200	228	564	379	253	204	2,558	7.12%
12:00	297	759	175	250	583	354	297	292	3,007	8.37%
12:30	653	339	240	120	395	246	306	406	2,705	7.53%
13:00	267	432	192	124	281	384	140	231	2,051	5.71%
13:30	416	268	67	12	226	170	56	274	1,489	4.14%
14:00	213	422	62	31	387	51	255	175	1,596	4.44%
14:30	342	261	36	96	434	230	154	237	1,790	4.98%
15:00	352	424	119	39	269	166	197	187	1,753	4.88%
15:30	185	323	130	171	191	124	175	121	1,420	3.95%
16:00	285	301	33	24	302	88	114	207	1,354	3.77%
16:30	406	238	118	27	155	145	159	283	1,531	4.26%
17:00	275	195	119	41	128	61	233	264	1,316	3.66%
17:30	176	286	73	215	100	141	199	138	1,328	3.70%
18:00	113	107	57	16	58	61	59	173	644	1.79%
18:30	48	44	14	43	156	89	103	170	667	1.86%
19:00	51	51	77	48	100	73	84	83	567	1.58%
19:30	18	7	54	184	98	219	52	107	739	2.06%
20:00	4	3	38	17	23	2	0	57	144	0.40%
Total:	5,886	6,806	2,359	2,298	5,737	3,567	4,204	5,070	35,927	100.00%

Figure 4.16: The population samples from 2014 to 2017 on a year-to-year and system-to-system basis, visualising the total number of interactions (i.e. touch down events) in relation to times of day.

from each other and differences only occurred on the account of chance. Therefore, the null hypothesis H_{test} being addressed was defined as follows:

- H_{test}: There is no difference between interaction data in 2014 (i.e. $>$ Week 17) and 2015 (i.e. $<$ Week 33).

Samples Overview: Interaction Data 2014–2017

Figure 4.16 shows the different population samples of interaction data[7] on a year-to-year and system-to-system basis. It refers to the 27 time segments denoted earlier and gradually highlights the total number of interactions. Time segments showing the highest number of interactions are additionally highlighted with a dark blue border. Seemingly, all years indicate such peaks between 12:00 and 13:00. In total, most interactions occurred at 12:00 (3,007 interactions), followed by 12:30 (2,705 interactions), and 11:30 (2,558 interactions). The figure incorporates material stemming from different circumstances (e.g. locations) which becomes exemplified by comparing interaction

[7] It is noted that the transitioning week (i.e. Week 33 of 2015) regarding the installation of a second screen was not considered in terms of *System 1*.

2015	14	57	106	213	348	138	236	246	483	505	759	339	432	268	422	261	424	323	301	238	195	286	107	44	51	7	3
2014	9	70	43	173	254	163	306	274	268	225	297	653	267	416	213	342	352	185	285	406	275	176	113	48	51	18	4
Difference	-5	13	-63	-40	-94	25	70	28	-215	-280	-462	314	-165	148	-209	81	-72	-138	-16	168	80	-110	6	4	0	11	1
Times of day	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00

Values: < 0 ≥ 0

Figure 4.17: The two samples from 2014 (i.e. weeks 18–52) and 2015 (i.e. < Week 33), including their pair-wise differences in relation to the varying times of day.

data from *System 1* in 2017 with material from all other years. This time period is the only one where a total of four additional segments indicate an extent of interactions that is larger than 80% of the sample's highest value (i.e. 306 interactions). Differences are also readily apparent when comparing the total number of interactions as well as the mean and standard deviation of the samples. This observation led to the definition of the following theoretical code:

- H_{26}: External factors such as different location setups affect the patterns of passers-by.

Test Preparations

The test design built on the fact that dependent pairs of observations were subjected to a statistical analysis. The values of two independent variables (i.e. *Years* including two levels and *Times of Day* encasing 27 levels) were related to one another and determined the value of a dependent variable (i.e. *Number of interactions*). Figure 4.17 provides an overview of the two samples. It demonstrates the individual pairs and their pair-wise differences (i.e. interactions in 2014 minus interactions in 2015).

Potential test candidates were the parametric Student's dependent t-test (Student, 1908) and the non-parametric Wilcoxon signed-rank test (Wilcoxon, 1945), whereas the distribution of the pair-wise difference was critical in determining the test (Longjian, 2018). The literature indicates that the t-test is "not sensitive to moderate departures from normality, [but] it is generally preferable not to rely on this feature" (Altman and Bland, 1995, p. 298). Data distribution was therefore initially investigated. A consensus exists that just visually checking distributions for normality is not sufficient (e.g. Altman and Bland, 1995; Öztuna, Halil, and Tüccar, 2006). Reportedly, it cannot be visually determined whether a sample distribution is statistically significant differ-

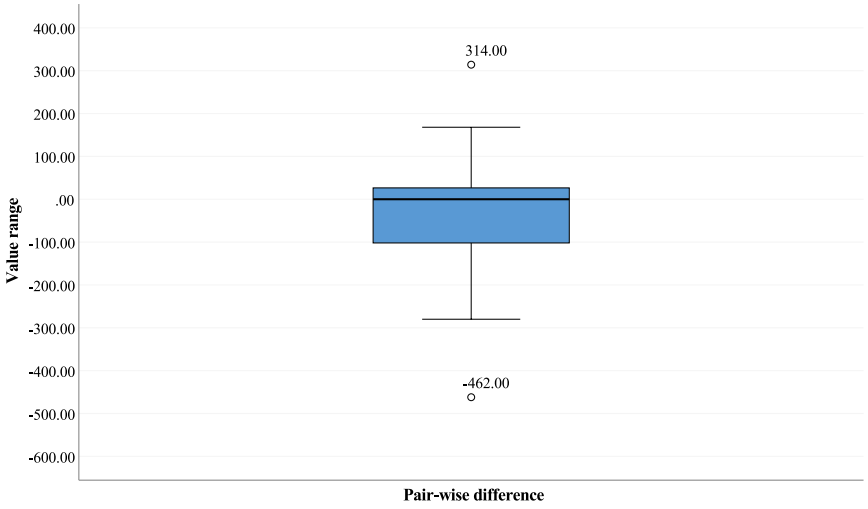


Figure 4.18: A boxplot showing the distribution of the pair-wise difference.

ent from a normal distribution (Öztuna, Halil, and Tüccar, 2006) hence the sample distribution was subjected to a visual investigation and a subsequent statistical analysis. There are different ways in visually presenting the distribution of data such as normal quantile-quantile plots (Q-Q plots), boxplots, and histograms (Öztuna, Halil, and Tüccar, 2006). In what follows, it was decided to leverage a boxplot visualisation according to Tukey (1977) and a histogram illustration.

Visually Interpreting the Distribution It became apparent that the distribution is likely to not be normally distributed. In the boxplot (see Figure 4.18), the mean (-34.07) and the position of the median (0.00) indicate that the pair-wise difference is skewed to some extent with a longer tail in the direction of negative values. Apparently, the magnitude of values in 2015 was sometimes notably higher. Both whiskers, including values in the range of 1.5 times the interquartile range (IQR)—here 138.00—are similar in length, meaning that values that are both the furthest away from the box and no outliers (-280 and 168) show likewise distances respectively from quartile 1 (-102.00) and quartile 3 (26.50). The overall value range is 776, including the two visualised outliers which reach beyond the scope of 1.5 IQR (314 and -462). However, SPSS did not indicate them as extreme outliers (i.e. $>$ 3.0 IQR). The two outliers correspond to the fact that most interactions in both years occurred roughly 30 minutes apart from each other during lunch time. These values were therefore not considered unusual as during

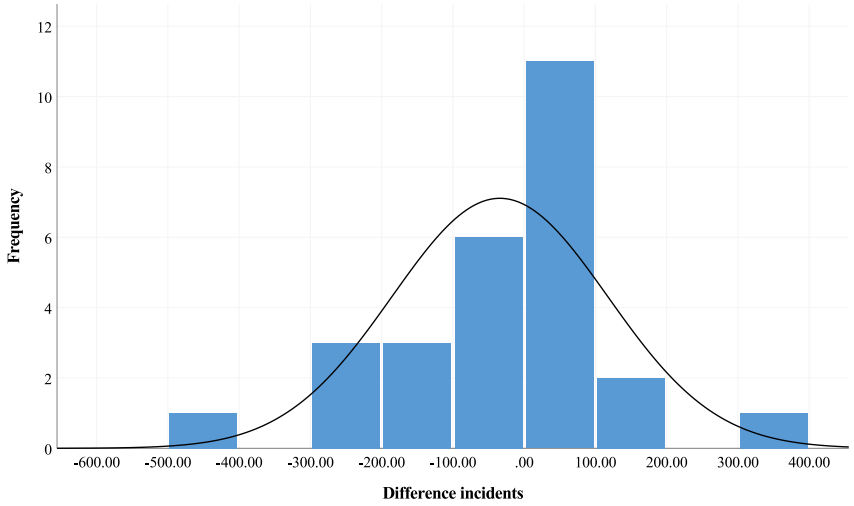


Figure 4.19: A histogram showing the difference incidents, the number of their occurrence, and a distribution curve of the pair-wise difference (mean = -34.07; SD = 151.53; skewness = -0.56; kurtosis = 1.92).

this time of day most utilisation repeatedly took place. The histogram (see Figure 4.19) shows that there is an equal amount of negative and positive values (excluding one case with the value of 0). Furthermore, there are many values directly surrounding the median, which is indicated by the lower height of the distribution curve and its higher kurtosis (1.92). Ideally, both skewness (-0.56) and kurtosis should equate to zero in a normal distribution (Ghasemi and Zahediasl, 2012). Apparently, skewness affects the distribution curve less than the kurtosis value does.

Testing the Distribution To elaborate on whether the aforementioned outliers markedly deviate from other members of the sample, the Grubbs test (Grubbs, 1969) was conducted. As the test intends to investigate both one value on the high and one value on the low side (i.e. left-sided and right-sided test), a critical p-value of .025 was chosen. Initially, however, a Shapiro-Wilk test (Shapiro and Wilk, 1965) was conducted as the Grubbs test prescribes that a pair-wise difference must follow a normal distribution. The Shapiro-Wilk test revealed that the pair-wise difference follows a normal distribution with S_{stat} (0.95) > S_{crit} (0.92) and $p = .24$. Consequently, the Grubbs test was continued and the test run demonstrated that neither of both outliers were statistically significant with G_{314} (2.30) < G_{crit} (2.86) and G_{-462} (2.82) < G_{crit} (2.86). As both outliers represent no extreme manifestations, they were retained in the sample as Grubbs (1969) suggests. In summary, while the test on outliers concurs with SPSS, the

Shapiro-Wilk test somewhat contradicted the visual interpretations of the distribution. Due to this contradiction, it was then decided to run both the parametric Student's dependent t-test and the non-parametric Wilcoxon signed-rank test.

Test Results

The t-test demonstrated that there were no statistically significant differences prevalent in the pair-wise sample with t_{stat} (1.17) < t_{crit} (2.06) and $p = .25$. Similarly, the Wilcoxon signed-rank test corroborated this finding with W_{stat} (141) > W_{crit} (107) and $p = .38$. Consequently, the null hypothesis H_{test} was not rejected as both tests suggested that differences in both samples occurred on account of chance. This fact is substantiated by a Cohen's d test (Cohen, 1988) that revealed an approximately small effect size (i.e. 0.20) with $d = 0.22$. Therefore, whatever caused apparent differences between both samples did not manifest to an extent that diminished chance to a significant probability. In any other case, it was expected that the differences between both samples would have substantiated markedly. It could hence be concluded that interaction data can be expected to show similarities when conditions underlying their occurrence do not severely differentiate from one another.

4.4.3 Cross-Comparing *Phase 1*, *Phase 2*, and *Phase 3*

Feedback during the group interview in *Phase 2* was supported by analyses of view events. For example, software developers responded that they preferred content in the *Jenkins* view. This was somewhat corroborated by analyses in *Phase 3* as both the information views *Jenkins* and *GoCD* showed strong usage. Compared to *Phase 1* and *Phase 2*, *Phase 3* issued the concern that user interface designs affect utilisation patterns. It was found that a substantial amount of view events was spent on gestures relating to the task of navigating through content. Consequently, *Phase 3* presented some quantifiable explanations as to why employees put forth their desire of a second display throughout the group interview. Additionally, *Phase 3* also provided a first insight to statistically interpret content utilisation over time as it illustrated usage on a year-to-year and system-to-system basis. In doing so, it corroborated findings from *Phase 1*. Notable increases existed in interactions in the morning (i.e. hypothesis H_1),

around noon (i.e. hypothesis H_2), and in the afternoon (i.e. hypothesis H_3). With respect to hypothesis H_4, it was also evident that the total number of interactions occasionally dropped notably. In terms of question Q_6, it seemed valid to assume that the data indeed showed some degree of saturation at the end of 2014 as similar patterns could be visually observed in subsequent years. Finally, *Phase 3* put forth that similar situational conditions such as team organisations, installation setups, and visualised content result in no statistically significant differences in interaction data.

4.4.4 Conclusion

The remainder now concludes *Phase 3*. This phase embodied the last stepping stone in conceptually and theoretically contributing towards an understanding of the Ambient Surfaces' long-term usage.

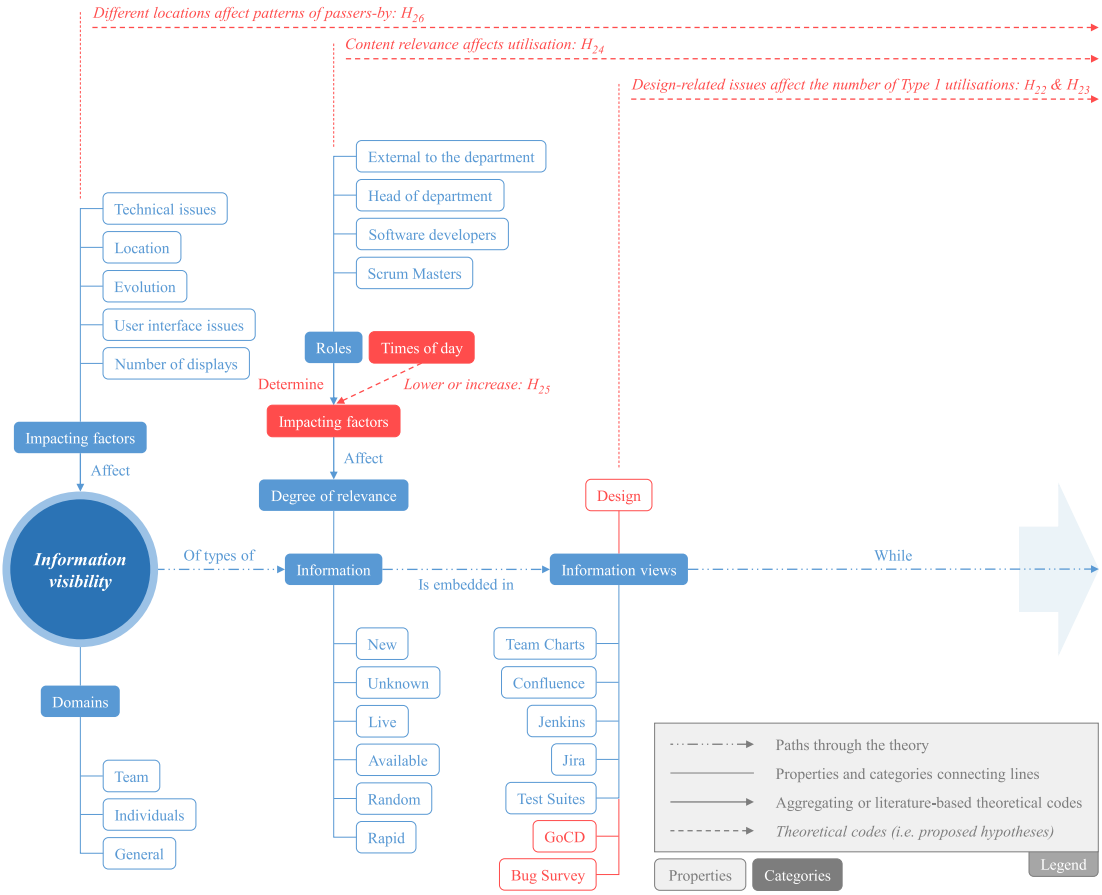
Addressing the Research Phase Question

In summary, conceptual and theoretical changes to the existing model were rather marginal. *Phase 3* largely surrounded the topics of user interface designs, content relevance, and situational conditions. In total, *Phase 3* contributed five new theoretical codes (i.e. hypotheses H_{22}–H_{26}).

Emergent Questions

Phase 3 primarily originated in concerns exemplified in research question Q_{10}. Other questions from *Phase 2* were ignored during this stage of research (i.e. Q_7–Q_9 and Q_{11}–Q_{14}). Nonetheless, the following questions emerged through *Phase 3* and complemented the list of existing questions:

- Q_{15}: How are the processes of intentionally searching for desired information and of exploring content out of sheer curiosity different from each other?
- Q_{16}: How do interactions related to the processes of intentionally searching for desired information and of curiously exploring content affect utilisation (i.e. in terms of the total number and the way of utilisation)?



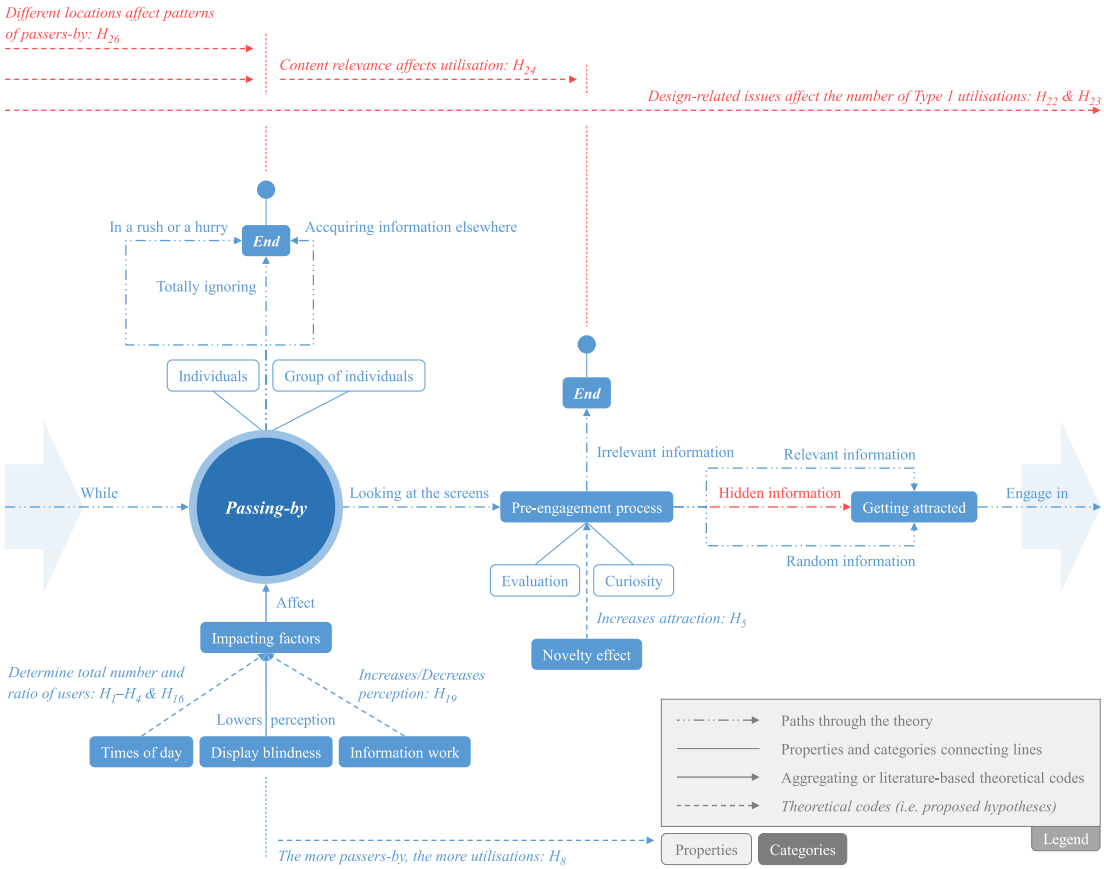
(a) The category of *Information visibility*.

Figure 4.20: A depiction of the revised theory, incorporating the pictorial models from *Phase 2*, enriched by findings from *Phase 3* (see highlighted elements in red).

- Q_{17}: What are the reasons for the varying levels of content relevance throughout a working day?
- Q_{18}: Do the presented statistically significant similarities in interaction data in 2014 and 2015 reoccur in other samples?
- Q_{19}: What are the potential metrics to identify the most relevant content?

Pictorial Model of the Revised Theory

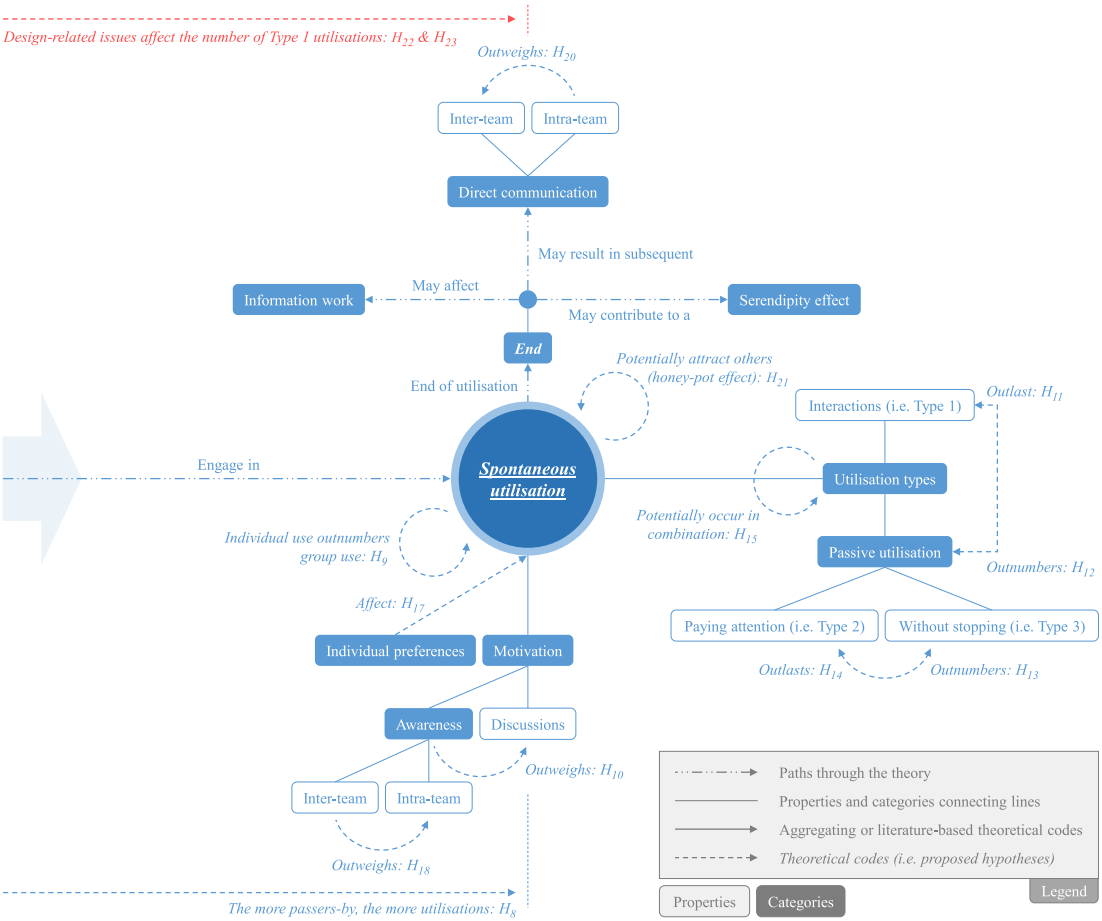
Analogously to both preceding phases, Figures 4.20a, 4.20b, and 4.20c consider the emergent theory's pictorial model of *Phase 3* and indicate changes in red. The conceptual and theoretical revisions are as follows. Firstly, it was found that different installation setups resulted in a change of utilisation, which can arguably be related to the differences in the patterns of passers-by (i.e. hypothesis H_{26}). Secondly, the



(b) The category of *Passing-by*.

Figure 4.20: Continued.

Degree of relevance in terms of *Information* can change over time as demonstrated by the *Jira* view in 2015 (i.e. hypothesis H_{24}). It is argued that a change of relevance can respectively affect both the *Pre-engagement process* (i.e. information is considered irrelevant) and the magnitude of *Display blindness* (i.e. one is totally ignoring the systems). Similarly, *Times of day* showed apparent differences in latent patterns of the varying information views (i.e. hypothesis H_{25}). Furthermore (i.e. hypotheses H_{22} and H_{23}), the *Design* of information views affected the total number of *Interactions (i.e. Type 1)*. Simultaneously, the efforts to unveil an information view (e.g. horizontally scrolling to find information) also entailed increases in the same type of utilisation. Both aspects are respectively considered in the *Pre-engagement process* as the desired information is *Hidden* and, consequently, utilisation takes place to unveil this information. Finally, two new views (i.e. the *GoCD* and *Bug Survey* view) added in 2017 were considered.



(c) The core category of *Spontaneous utilisation*.

Figure 4.20: Continued.

4.5 *Phase 4*: Respondent Validation

Two attendees explicitly underlined their consensus with the illustrations discussed. *Ms Fuller* found the explanations understandable and saw her usage reflected in the depictions. Similarly, *Mr Pink* corroborated that many crucial aspects were incorporated into the visual representations which were in line with his experiences. Overall, attendees were rather specific in their feedback and stressed the importance of certain aspects, whereas some feedback described issues in the grander scheme of things. These topics are presented below, while the following synonyms for names are used: *Mr Orange, Ms Ralston, Mr Vega*, and *Mr Blue* (Scrum Masters); *Mr Crash*, *Ms Fuller*, and *Mr Warren* (software developers); *Mr Moguy* (computer science student); and *Mr Pink* (head of department).

4.5.1 Location

The location—notably the relocation in early 2017—played an important role throughout the group interview. It had a crucial impact on the usage, as both *Mr Blue* and *Mr Pink* concurred in their feedback. Due to the fact that a table football setup was located beside the Ambient Surfaces from mid-2017 and the systems were located in a hallway that led to the canteen, *Mr Blue* concluded that the group of active users had substantially increased in the new building. *Mr Pink* added that utilisation in general (i.e. including passive cases) increased as the audience was mostly restricted to department personnel in the old building. He also stressed the fact that because the toilets were located near the Ambient Surfaces in the new building, this may have additionally affected utilisation. *Mr Warren's* observations corroborated the audience issue as he found that at midday there were typically more people from diverse backgrounds walking through the building. *Mr Vega* noted that he had generally observed different audiences in the two buildings. In the new building, he often recognised audiences that differed from typical users in the old building, especially at midday and in the evening, when people were allowed to play table football. In this context, *Mr Vega* and *Mr Blue* also discussed the physical characteristics of both buildings. For instance, in the old building, one had to pass by the Ambient Surfaces when arriving at work. In contrast, substantially more staff members from the entire company were able to access information on the screens in the new building as summarised by *Ms Fuller*.

Conceptually, a comment from *Mr Pink* was considered as he positively highlighted the location as a means of distributing otherwise hidden information. Also, the following hypothesis was proposed:

- H_{27}: Times of day affect the type of audience that is passing by the Ambient Surfaces.

4.5.2 The Category of *Information visibility*

Mr Pink concluded that hampering access to information should be avoided due to characteristics of the user interface such as the necessity to unveil information by interaction gestures. This conclusion was supported by *Mr Vega*, as he also experienced

challenges in the way information was conveyed. *Mr Pink* consequently concluded that one can hardly deploy enough displays to account for all the different users and roles. It was further indirectly supported that roles indeed affect information relevance, as *Mr Crash* explained when stating that he was less interested in the team burn down charts.

While the preceding did not contribute any new theoretical insights, it became apparent that information relevance is conceptually affected by temporal attributes beyond times of day. This was corroborated by *Mr Blue* and *Mr Orange*, who stressed the importance of displaying information according to current activities in the department. To summarise this issue, hypotheses H_{25} was reformulated:

- *H 25* (reformulated): Content relevance depends on temporal attributes such as times of day and current activities in the department.

4.5.3 Display Blindness and the Novelty Effect

It was highlighted by *Mr Pink* that some people ignore the Ambient Surfaces. However, he noted that this was a somewhat expected circumstance. In summary, the feedback conceptually and theoretically contributed as follows.

According to *Mr Blue*, the novelty effect can additionally originate in the value of a piece of information. For instance, people reportedly tended to investigate content more frequently when "bad news" (e.g. broken builds) was presented on the screens in red. Furthermore, both *Mr Pink* and *Mr Blue* underlined the possibility of iteratively adding new content to counteract display blindness. The following theoretical code was thus put forth:

- *H 28*: Repeatedly provoking the novelty effect mitigates the prevalence of display blindness.

Mr Pink highlighted that a piece of information offer should generally consider changes over time in the department. Overall, this feedback led to a reconsideration of the novelty effect's representation in the pictorial model. For instance, its occurrences are now specified—that is, the novelty effect can occur initially, but can also occur time and time again.

4.5.4 The Category of *Passing-by*

Fundamentally, *Mr Warren* stressed the criticality of easily conveying information at a glance to passers-by as the screens are otherwise of little assistance. Overall, three additions to the existing model resulted from the feedback. Firstly, *Mr Blue* added that the theory was missing to explain the case that one is potentially passing by the systems when they are occupied. Secondly, he contrastingly also reported that he regularly stopped in front of the Ambient Surfaces when new blog articles were displayed in order to draw other employees' attention to this content. Lastly, *Ms Fuller* underlined earlier findings that people tended to look at the screens while passing by as she described her usage similarly. However, it became apparent that it is seemingly crucial whether people are directly facing the displays while walking past them. In summary, the following theoretical codes were proposed:

- H_{29}: System vacancy affects the decision-making process to further engage while someone is passing by.
- H_{30}: Peoples' facing position while passing by affects the general notion to further engage.

4.5.5 Attracting Others

Mr Blue compared the impact of the systems to a coffee machine as he observed that people engaged in situations in front of the Ambient Surfaces because others were already standing there (i.e. the honey-pot effect). As indicated earlier, *Mr Blue* also proactively leveraged this characteristic to draw attention of others to certain content. *Mr Pink* concurred with *Mr Blue's* statement. Generally, both *Mr Pink* and *Mr Blue* stressed the issue of being attracted to participate in informal communication situations with other colleagues. However, this feedback did not result in any visual updates of the existing depictions.

4.5.6 The Core Category of *Spontaneous utilisation*

Two incidents throughout the session shed further light on the spontaneous nature of utilisation. Firstly, although *Mr Blue* purposely tried to draw others' attention to par-

ticular content, he did so only in cases when he was spontaneously passing by. Secondly, *Mr Crash* reported that he typically did not utilise the systems on purpose as all information was readily available and more conveniently available from a desktop computer. These statements, however, also led to no additional changes to the illustrations.

4.5.7 Information Transparency Implications

The group interview also touched on the topic of implications with respect to information transparency. Yet, this feedback regarded rather the grand scheme of things and contributed no revisions to the existing visual representations.

Mr Blue reported on cases where software developers were confronted by personnel from higher management due to the displayed information. Supposedly, these incidents were rather unpleasant for the corresponding staff members. Similar experiences were provided by *Mr Warren* as people were occasionally worried about a potential misinterpretation of the displayed information. However, *Mr Blue* also positively emphasised the department's attitude towards making internal information transparent to others as this contributed to the company's cultural development. Reportedly, not every department was willing to provide such information. *Mr Pink* concurred with the statements from *Mr Blue* and added that such systems may assist in achieving a cultural shift. *Mr Crash* also welcomed such a degree of transparency contrary to investigating concerns in retrospect. However, a precondition would be that higher management is constructively participating in this process. Finally, *Mr Vega* noticed changes in terms of communication (i.e. the "wording") as discussions with others reportedly became of a more constructive nature.

4.5.8 Integration

Finally, the respondent validation provided some insights relating to the daily integration of the Ambient Surfaces at Werum. This feedback, however, also led to no further visual revisions of the theory. Firstly, *Mr Pink* experienced that Scrum Masters were the most predominant users. Secondly, *Mr Crash* shared his anecdotal experience in using the systems. He typically walked past the Ambient Surfaces in the morning when arriving at work. In a humorous sense, *Mr Crash* said that depending on the

presented information in the views *Confluence* and *Tetris*, he decided to whether turn on his computer or to leave work right away. Reportedly, he would miss such kinds of information in the morning as these were readily available and indicated the day up front. Lastly, *Mr Orange* experienced that the systems became more stable over time. He also highlighted the fact that the restart button was incorporated at some point. Both aspects assisted him to continuously operate the systems, which he perceived as relevant.

4.5.9 Conclusion

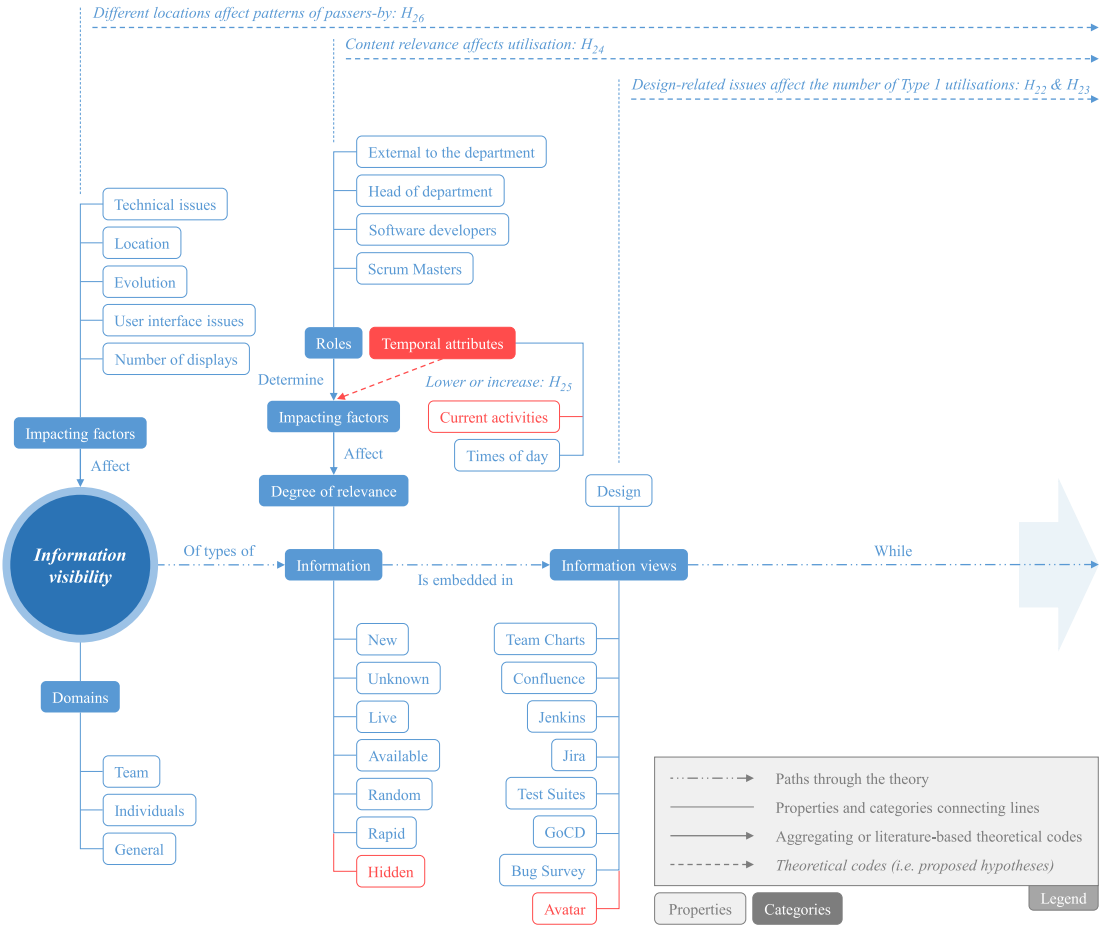
This section embodies the closing stepping stone in generating theory in this work. No additional questions were formulated during this stage of research.

Addressing the Research Phase Question

It can be concluded that participants largely concurred with pictorial depictions presented throughout the group session. Feedback rather suggested additions to the existing model than contradicted it with its fundamental building blocks. Similar to *Phase 3*, conceptual and theoretical changes were of marginal extent. Instead, attendees primarily elaborated on certain parts of the theory such as the location. *Phase 4* contributed four additional theoretical codes (i.e. hypotheses H_{27}–H_{30}).

Pictorial Model of the Final Theory

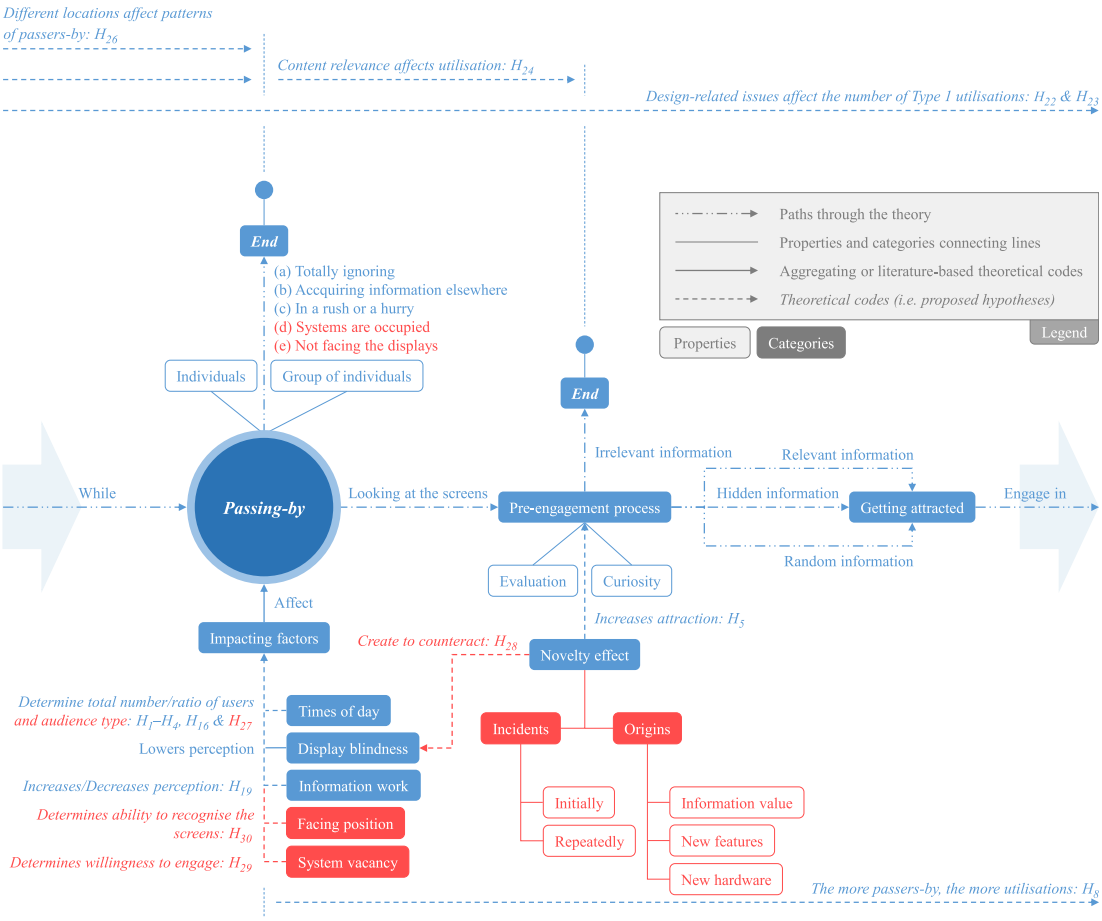
Feedback added visual revisions to the topics of information relevance, types of information, the category of *Passing-by*, the novelty effect, and finally, the core category of *Spontaneous utilisation*. Analogously, these changes are incorporated into Figures 4.21a, 4.21b, and 4.21c, while the red colour contrasts findings to *Phase 3*. In short, these revisions are as follows. Firstly, the category *Temporal attributes* as an impacting factor for the degree of information relevance was added. Information relevance apparently did not only depend on specific *Times of day*, but also on *Current activities* in the department. Secondly, *Hidden* information was introduced as another type of information. Thirdly, statements suggested that *Times of day* regarding the process of *Passing-by* affect the audience type. Fourthly, the process of *Passing-by*—and con-



(a) The category of *Information visibility*.

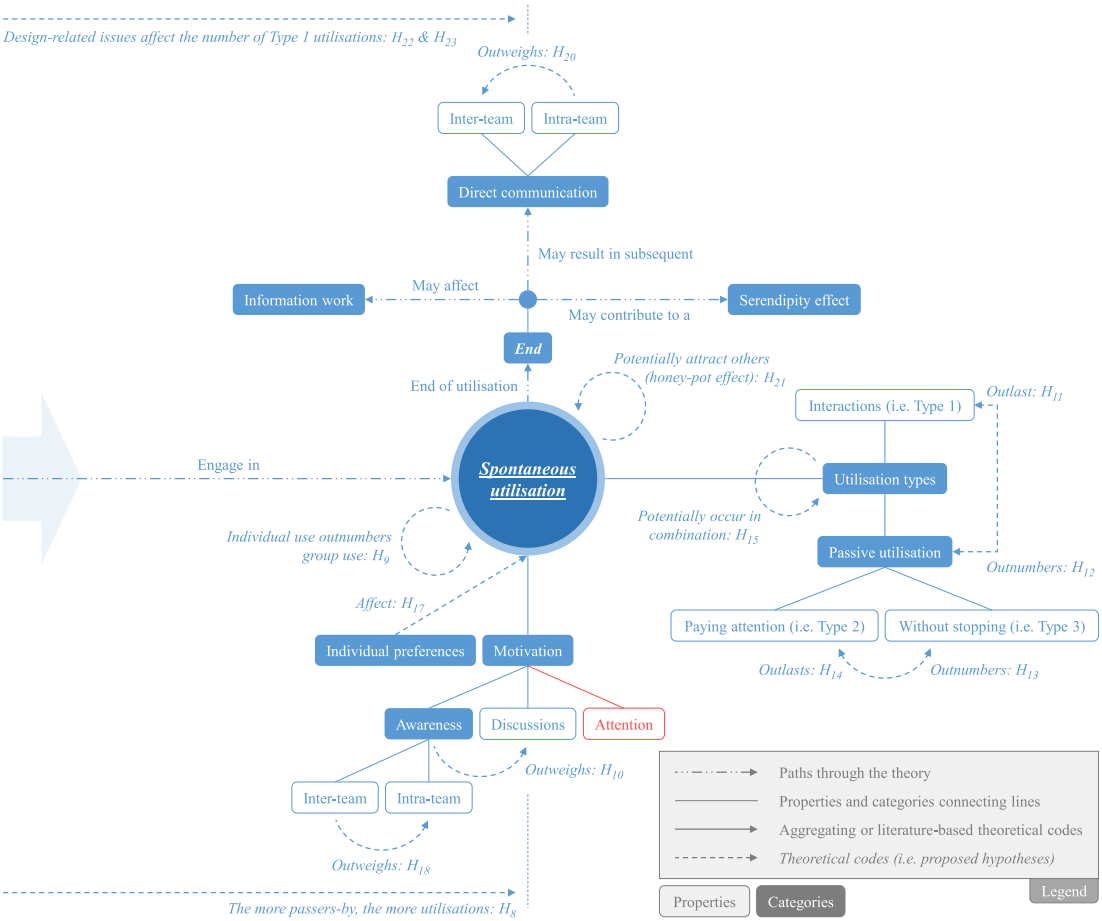
Figure 4.21: An illustration of the final theory, including the visual changes stemming from the respondent validation (see highlighted elements in red).

sequently utilisation—is affected by one's *Facing position* towards the systems. Fifthly, *System vacancy* also plays an important role as people may walk past the systems, when they are already in use. Sixthly, the novelty effect shows three sources of origin: *New hardware*, *New features*, and *Information value*. It is now also linked to display blindness as a means to counteract this effect. Overall, the novelty effect was observed in *Incidents* throughout the beginning of this research (i.e. *Initially*), but also later on (i.e. *Repeatedly*). Seventhly, incidents of *Spontaneous utilisation* are also leveraged to proactively attract *Attention* of others. Lastly, one new view (i.e. the *Avatar* view) added in 2018 was considered.



(b) The category of *Passing-by*.

Figure 4.21: Continued.



(c) The core category of *Spontaneous utilisation*.

Figure 4.21: Continued.

4.6 Summary

This chapter illustrated a practical systematisation of GT's two core mechanisms—constant comparison and theoretical sampling. Their application resulted in 30 theoretical codes that were proposed to indicate relationships between the varying substantive codes. Therefore, Section 4.2 set out with analyses of quantitative interaction data and indicated the first directing hypotheses that guided subsequent activities. Results indicated, for instance, that utilisation is somewhat related to informal occasions such as lunch breaks. In summary, *Phase 1* contributed seven theoretical codes. Section 4.3 then elaborated on mostly qualitative data stemming from observations, a group interview, and an online survey. During this stage of research, the core category of *Spontaneous utilisation* emerged. Together with the two other categories of *Information*

visibility and *Passing-by*, these categories contributed the conceptual building blocks of the emergent theory. Taken together, it seemed that these three categories were starting to be able to "handle the data theoretically" (Glaser, 1978, p. 56). *Phase 2* resulted in a major revision of the pictorial model of *Phase 1* on both a conceptual and a theoretical level. Overall, *Phase 2* contributed 14 additional theoretical codes. Section 4.4 then enriched analyses largely through descriptive statistics and statistical tests. This phase suggested, for instance, that long-term interaction data stemming from similar conditions shows no statistically significant differences. Analyses in *Phase 3* resulted in five new theoretical codes. Finally, Section 4.5 concluded the process of generating theory in this work. In *Phase 4*, a respondent validation was conducted and the resulting feedback was incorporated into the last revision of the theory. It led to five further theoretical codes that were considered in the pictorial model.

The thesis now continues with Chapter 5, which attempts to critically reflect on this research and its findings.

Chapter 5

Discussion

> "I believe it's [grounded theory] a general all-round method, but the way you choose to do it—as long as you have theoretical sampling, constant comparison, ask some sort of questions—*how* [emphasis as in original] you actually do it is individual. We all do it differently."
>
> —Juliet Corbin in Morse et al. (2009, pp. 236–237)

5.1 Introduction

This chapter puts forth a critical stance on the present research and simultaneously indicates its contributions to existing knowledge. The chapter therefore sets out with Section 5.2, which presents a critical reflection on a methodological level. Subsequently, Section 5.3 elaborates on the contributions of this work. Section 5.4 then revisits the

topic of trustworthiness in GT methodology. Before summarising the discussion in Section 5.6, Section 5.5 presents the limitations of this research.

5.2 Critical Methodological Reflection

For a critical reflection on a methodological level, aspects are examined through two different lenses: firstly, issues relating to the choice of GT methodology (see Section 5.2.1); and secondly, experienced challenges with its actual application (see Section 5.2.2).

5.2.1 The Choice of Grounded Theory

This work does not intend to make the argument that the chosen methodological approach is the *ultima ratio* to conduct every (longitudinal) ambient display in-situ study. For example, Siek et al. (2014) recommend a more sequential organisation of the research process, where analyses are intended at the end of an enterprise. In fact, this post-deployment approach is also chosen by some GT studies in the context of HCI and CSCW (Muller, 2014). Furthermore, other circumstances may demand a different methodological choice (e.g. limited time resources). This thesis seeks to illustrate a way to methodologically guide ambient display field deployment research. As Glaser (1998) summarises, GT is just another methodology to conduct research.

However, from its outset, this research fundamentally strove towards understanding what Siek et al. (2014, p. 122) call "naturalistic usage". It was committed to the challenge that research prototypes must be robust and typically do not withstand daily use in authentic environments (Nunamaker Jr. et al., 2015; Siek et al., 2014). Consequently, several issues occurred throughout the entire study. As the Ambient Surfaces changed rather regularly, so did the environment, including team numbers and meeting schedules to name but a few. GT's notion of generating theory assisted in mitigating bias and staying sensitive towards data. For example, sometimes there were no interactions during an entire week in 2014. Immediately, questions were posed and possible explanations were theorised about. Normally, this led to activities such as writing an email to the project partner to investigate an issue further. If all analyses had been conducted post-deployment, such investigations would have at best accounted for notable time-

intensive activities. It is highly questionable whether such investigations conducted retrospectively would have produced any reasonable explanations. Generally, it is most certain that the Ambient Surfaces would not have been in operation as of 2019 had the author not committed to this engagement. Issues such as changes in the toolchain (e.g. obsolete tools) or in the local network infrastructure, as well as unresolved stability issues, would have inevitably resulted in a discontinuation of use. In this regard, the selected primary data source served as a sensitive indicator to quickly start wondering about the data. It was of special help, when the research commenced, but also later during the study (e.g. to isolate the novelty effect).

Principally, it felt challenging to convey the tacit knowledge of issues that are not directly presented in charts, diagrams, and statistical tests to the reader. However, as one had to constantly compare data and theorise about implications, GT ensured progress was explicitly tracked while, for instance, asking questions and taking notes. Here, custom documentations did benefit the overall progress and helped in investigating issues further. Only by bringing these sometimes intertwined issues to attention, it is believed that field deployment reports reach their full potential and the reader is able to enjoy a text to its full extent. By introducing scientific rigour to an area of such a demanding nature, reports like the present thesis may arguably assist in mitigating the scant knowledge on how to go about in such enterprises.

Finally, the author's academic environment, including the *Creative Space for Technical Innovations*[1] laboratory at the HAW Hamburg initially shaped this research (e.g. to embark upon epistemological and methodological questions). Principally, there is a rather strong attitude towards interdisciplinary research in this laboratory. Aside from personal interest in the substantive area, which is vital for a research endeavour (Glaser, 1998), this circumstance and subsequent literature reviews regarding GT methodology led to the decisions described in this document.

[1] https://csti.haw-hamburg.de/

5.2.2 Experienced Challenges

Conducting this research on a methodological level was somewhat challenging—vividly exemplified by the fact that many software engineering GT studies lack methodological detail (Stol, Ralph, and Fitzgerald, 2016). Glaser (2008) repeatedly argues that GT can be conducted with any kind of data yet scholars fail to provide fruitful directions in conducting GT with quantitative material other than secondary survey data. The same holds true for the application of mixed-methods approaches in GT, which range from rare to non-existing (Jørgensen et al., 2013; Walsh, 2015). Consequently, in this research it was required to deal with these circumstances from the outset. Shunning away from this challenge by, for instance, solely considering one type of data, could have resulted in a less satisfactory substantive theory (Jørgensen et al., 2013; Walsh, 2015).

It was also difficult to achieve what Glaser (1998) indicates about quality as it arises from how well one is adhering to GT mechanisms. Therefore, and as recommended elsewhere (Timonen, Foley, and Conlon, 2018), the author initially tried to become familiar with and extract the foundations of GT methodology. This ambitious attempt was intended to avoid falling into the trap of using GT *à la carte*, meaning one is only borrowing specific GT practices (Stol, Ralph, and Fitzgerald, 2016). However, with its year-and-a-half learning curve (Glaser, 1998), GT on its own can be considered a demanding learning action. The author commenced this research under the influence of what Glaser (1998, p. 5) refers to as "minus-mentoring", meaning that there was no one available who could have trained him accordingly. Knowledge was gained by reading books, publications, and other classic GT doctoral dissertations. Inevitably, this demanding nature affected the overall progress and also resulted in the decision to largely exclude the extant literature.

5.3 Contributions

This work's contributions primarily surround the two research gaps identified in Section 2.5. Section 5.3.1 summarises these main contributions: firstly, contributions regarding the lack of examples of longitudinal ambient display field deployments (i.e. *Research*

gap 1); and secondly, contributions relating to methodology issues in such enterprises (i.e. *Research gap 2*). Furthermore, this thesis adds to existing knowledge to further extents, which is elaborated in Section 5.3.2.

5.3.1 Main Contributions

The first main contribution stems from the fact that the present thesis thoroughly illustrates findings from an exemplary long-term field deployment study of a custom ambient display solution. As elaborated on in Chapter 2, there have been recent calls that warrant further longitudinal in-the-wild research. This thesis, with its explicit and rich descriptions, embodies such an example. The rare value of this thesis's long-term findings is exemplified by a 2016 publication (Schwarzer et al., 2016) which illustrates selected results from this research. Furthermore, the generated theory can be fundamentally understood as one of the few theories of ambient displays in the wild as there are apparently only little theoretical advances. For instance, Alt et al. (2012) comment on a lack of general theories in the related field of public displays.

The second main contribution primarily concerns ambient display in-situ research on a methodological level. In essence, this contribution portrays ways for other researchers to conduct novel research. To this end, this thesis suggests classic GT as a way of conducting research in such enterprises. It proposes a means of coping with the scarce methodological advances in ambient display field deployment research. A 2019 publication (Schwarzer et al., 2019) introduced the methodological underpinnings of this work and demonstrates their practical systematisation throughout the study's early stages (i.e. *Phase 1*). Compared to the first main contribution, this contribution is arguably more far-reaching as it targets at methodological issues. This includes:

- This research demonstrates a practical systematisation of both core processes in GT, namely constant comparison and theoretical sampling. The literature remains silent about how to proceed during the constant comparison process and fails to indicate what constitutes fertile comparison candidates to develop a theoretical model (Boeije, 2002). It is essential to understand what Boeije (2002, p. 394) refers to as the "'production' [apostrophes as in original] procedure"

that typically takes place during analyses. Additionally, the implications of data magnitude for the theoretical sampling process are not well understood (Stol, Ralph, and Fitzgerald, 2016). Ultimately, the systematisation approach may contribute a means to "make GT more comprehensible and accessible ... for the novice researcher" (Timonen, Foley, and Conlon, 2018, p. 8).

- The present work envisions the utilisation of quantitative data in GT research. There have been no recent attempts in this regard (Glaser, 2008).

- As the introduced practical systematisation approach was respectively utilised with quantitative and qualitative data, this thesis puts forward a rare means of utilising a mixed-methods approach in GT research.

- Although memos are considered the core stage in GT (Glaser, 1978), Corbin and Strauss (2015) recently noted that they are not well understood. This research illustrates an exemplary way of applying memos during the process of analysing quantitative and qualitative data. For example, based on elaborations in quantitative GT (Glaser, 2008), Section 4.2 leveraged cross-tabulations to pose hypotheses about quantitative interaction data. These cross-tabulations served as memos in this research as they allowed ideas for the emergent theory to be captured (Glaser, 1998). Further examples are memos relating to observations from where they came in the form of tallies or illustrations simultaneously incorporating different types of data such as noise levels and the author's time of presence (e.g. see Figure 4.10). Each of these memos assisted in constantly comparing the corresponding data at hand.

- As theoretical sensitivity is generally a challenging concept (Bryant, 2009), this research contributes exemplary illustrations as to how sensitivity towards the data was incrementally developed.

Further contributions regarding GT methodology are discussed below when drawing attention to domains other than the particular case of ambient display research.

5.3.2 Additional Contributions

This section addresses contributions that feel less profound but nonetheless deserve a special mention. These contributions include the topics of display blindness, the novelty effect, ASD, as well as the domains of software engineering, CSCW, and HCI.

5.3.2.1 Display Blindness and the Novelty Effect

Results from this thesis contradict, concur with, and extend related literature on display blindness in the context of large display deployments. While, for instance, Huang, Koster, and Borchers (2008) found that only a small portion of users were looking at the screens in their study, Dalton, Collins, and Marshall (2015) underlined the observation from this work that people tend to look at the Ambient Surfaces while walking past them. Furthermore, both aforementioned publications further corroborated the issue that typically passers-by looked at the screens very briefly (i.e. *Type 3* utilisations). Principally, research on display blindness requires real-world data, still lacks momentum, and was only conducted in short-term studies lasting no longer than a couple of days (Memarovic, Clinch, and Alt, 2015). In this vein and by following recommendations (Memarovic, Clinch, and Alt, 2015), the thesis contributes detailed information such as on the location, users, content, screen properties, long-term latent patterns, numbers of passers-by, and types of utilisation. For this reason, the conditions under which conclusions were drawn are transparently present to the reader. This thesis may also provide some answers to the question of why there is an apparent tendency towards short and brief interactions such as with public displays (Memarovic, Clinch, and Alt, 2015). People typically engaged with the Ambient Surfaces in situations such as lunch breaks—they had not been planning on intentionally interacting with the systems.

However, contributions with respect to the novelty effect are more profound. In a 2018 co-authored publication (Koch et al., 2018), existing knowledge on the effect and related topics was collated, findings were discussed surrounding the effect's predominance, and a set of influencing factors was proposed. The paper was revised and written collaboratively by all authors, while this thesis contributed a reflection of the effect in

a long-term research endeavour. Two aspects were highlighted: firstly, the prevalence of this effect at the study's beginning (i.e. an initial novelty effect); and secondly, its reoccurrence after changes had been applied to the Ambient Surfaces (i.e. a reoccurring novelty effect). It was demonstrated that findings from this research concur with the literature to some extent as most interactions in 2014 occurred during the first 4 weeks after deployment (e.g. Gallacher et al., 2015; Hazlewood, Stolterman, and Connelly, 2011). However, it was also shown that certain circumstances demanded an extension to this time period so as to avoid skewing conclusions drawn from analyses. Ultimately, the paper stated that the novelty effect is still missing a formal definition.

5.3.2.2 Domain of Agile Software Development

The value of this research is also underlined by the fact that there are just a few empirical studies on large-scale ASD (Dingsøyr et al., 2018; Rolland, 2016). In a similar vein, management-orientated approaches, such as Scrum, are the most under-researched agile representatives compared to their adoption in the industry (Dybå and Dingsøyr, 2008). This work provides an exemplary empirical lens on such a context. For instance, findings revealed what kind of information was relevant to staff members. Fundamentally, more theory-based research is warranted in ASD (Dingsøyr et al., 2012). The theory proposed here can certainly also be considered in this regard. Lastly, as this research was conducted in a matured agile context, the thesis further contributes towards the lack of knowledge on agile teams in such environments (Dybå and Dingsøyr, 2008).

5.3.2.3 Domain of Software Engineering

Generally, there are only a few studies in the domain of software engineering that utilise GT (Stray, Sjøberg, and Dybå, 2016). GT is considered relatively new to this context (Stol, Ralph, and Fitzgerald, 2016; Stray, Sjøberg, and Dybå, 2016). Stol, Ralph, and Fitzgerald (2016) further argue that GT in software engineering research is non-trivial and found that it suffers from *method slurring*, which refers to claiming the use of a methodology without following its actual guidelines (Baker, Wuest, and Stern, 1992). They also note that GT studies in software engineering generally lack methodological depth. Consequently, it is difficult for readers to assess a study's rationale. Stol, Ralph,

and Fitzgerald (2016) therefore invite future research to provide sufficient detail on their methodological descriptions. With both Chapter 3 and Chapter 4, this work attempts to contribute rich elaborations on how one can proceed with GT methodology.

This work also responds directly to calls that warrant more and better collaborations between academia and industry (Sjøberg, Dybå, and Jørgensen, 2007). All of the presented findings build on a multiple-year collaboration between the author and the participating company.

5.3.2.4 Domains of Human–Computer Interaction and Computer-Supported Cooperative Work

Similarly to the discipline of software engineering, there exists some confusion about what constitutes GT in HCI and CSCW research (Muller and Kogan, 2012). In this regard, Muller and Kogan (2012) propose two directions for future research. Firstly, they stress the relevance of bringing the process of constant comparison to the fields of HCI and CSCW to iteratively develop theory. Secondly, as the use of literature is contested in GT research, they call for HCI and CSCW studies to touch on this issue. This research advances these discussions as it provides exact details on both the constant comparison process and the incorporation of literature.

Furthermore, the definition and practices of GT in HCI and CSCW suffer from a blurring, which leads to difficulties in assessing a study's quality and rigour (Muller, 2014). Concerns of quality are still an unresolved topic in the GT community as Muller (2014) further elaborates. However, he invites future studies to be specific about methodological choices made during the research process (e.g. explicitly stating the GT variant) to mitigate this existing vagueness of the methodology's application. Particularly, Chapter 3 advances on this issue by rigorously explaining individual choices made for the present research.

5.4 Trustworthiness of the Theory

In Chapter 3, it was indicated that GT research considers certain criteria to discuss the trustworthiness of a study. This section returns to and reflects on the criteria fit (see

Section 5.4.1), relevance (see Section 5.4.2), work (see Section 5.4.3), and modifiability (see Section 5.4.4) by considering the proposed theory.

5.4.1 Fit

The core category of *Spontaneous utilisation* in combination with the two categories of *Information visibility* and *Passing-by* adequately reflect the patterns prevalent in the data. Firstly, they emerged while triangulating data in the constant comparison process during *Phase 2* (see Section 4.3). The core category emerged from the data and builds on the material at hand and not on any preconceived ideas or hypotheses. Secondly, the core category constitutes the main concern of participants in resolving how to describe their utilisation behaviour. The proposed theory places the category of *Spontaneous utilisation* at its heart and exemplifies the usage of both Ambient Surfaces by outlining its origins in spontaneity. The other two crucial categories *Information visibility* and *Passing-by* interact with this central concept and inform it.

5.4.2 Relevance

The emergent theory has arguably grab for both study participants and practitioners. In fact, the respondent validation in *Phase 4* (see Section 4.5) underlined the overall relevance as respondents felt that their usage was reflected in the conceptual representations. Also limiting access to the extant literature assured relevance as the core category emerged directly from the data. Practitioner relevance of the emergent theory arises from the circumstance that existing knowledge is lacking in general theories, which is, for instance, demonstrated in the related domain of public displays (Alt et al., 2012).

5.4.3 Work

A theory that fits and shows relevance also works (Glaser, 1998). The theory introduced here has predictability. It explains what is happening in the area of substantive inquiry and allows conclusions in light of utilisation behaviour to be drawn over time. Considering the specific type of ambient media and the environmental conditions, the theory suggests that such devices were, are, and will likely be used in a foremost spontaneous

manner. Time and again, triangulated data was elaborating on the spontaneous nature of utilisation and rarely showed indications of deliberate usage.

5.4.4 Modifiability

Finally, the proposed theory provides modifiability. Again, new data is neither considered wrong nor missing as a theory is readily modifiable by further material. In the end, supposedly inaccurate or lacking data only represents a new piece of data to be included in the overall analysis. As the emergent theory provides a conceptual model, new categories and properties can be readily integrated and may extend or revise the theory. Its modifiability was demonstrated by the various evolving pictorial models that concluded each research phase in Chapter 4. The theory has fit, work, and relevance, whilst remaining open to further modifications.

5.5 Limitations

Limitations stem from personal concerns (see Section 5.5.1), generalisation implications (see Section 5.5.2), not considering the extant literature (see Section 5.5.3), the application of GT (see Section 5.5.4), and the conduct of the different data collection methods (see Section 5.5.5). The following paragraphs elaborate on these limitations.

5.5.1 The Researcher

The quality of the outcome of this research is limited to the author's knowledge, skills, understanding, and experience of research. While Glaser (2009) notes that the best GT research is conducted by the beginner, the author, as a novice GT researcher, may have limited the study to a lesser or greater extent. For example, the inexperience of being theoretically sensitive may have affected how the methodology was actually conducted. This novice stance similarly influenced the various data collection methods which are discussed in Section 5.5.5. Finally, the familiarity with the area of inquiry may have also limited the study as it was hardly possible to deny experiences from preliminary studies.

5.5.2 Generalisation

Every GT has its own degree of generalisation as conceptualisation goes beyond place and time. Glaser (1998) describes this feature in terms of the core category's characteristic to be readily transferred to other substantive areas. A limitation arises from the fact that this work builds on one particular substantive area with data stemming from one specific German ASD context. It should also be noted that there is a variety of notification modalities that ambient media can leverage—including hearing, vision, haptic, olfaction, and taste (Börner, Kalz, and Specht, 2013). Accordingly, the results are limited to ambient media that largely builds on one's vision and haptic by leveraging large and interactive displays. These limitations should be thoughtfully considered when transferring concepts from this work to other substantive areas.

5.5.3 Literature

Mostly due to limited time resources, further constraints emerged from the decision to not compare the generated theory to the extant literature throughout the processes of sorting and writing up the theory. Again, Glaser (1998) underlines that a substantive theory has contribution strength on its own. However, it is likely that comparisons with the extant literature would have widened the conceptual and theoretical implications of the proposed theory.

5.5.4 Methodology

Doing GT is a highly individual endeavour (Heath and Cowley, 2004; Morse et al., 2009). Consequently, another researcher would have very likely come to other conclusions as vividly described by Morse et al. (2009) and would have developed his or her own set of practices (Muller and Kogan, 2012). The elaborations in this work reflect a personal interpretation of classic GT and consequently potentially entail a further limitation. Nonetheless, the author strove towards maintaining a critical attitude to the chosen approach, assumptions, and preconception to mitigate personal bias. It is, however, not claimed that the research followed the notion of an impartial view; rather it considered the researcher as a constituent part of it.

5.5.5 Methods and Data

Limitations also stem from the fact that the generated theory largely builds on various data that was collected for different periods of time (i.e. observations, the survey, and interaction data) and at specific points in time (i.e. the group interview and the respondent validation). This circumstance may have limited the research's scope to a lesser or greater extent. Available time resources and personal exhaustion particularly delimited the process of data saturation. Consequently, additionally collected data in the form of new interchangeable indicators may have extended or revised the theory proposed here.

Furthermore, the implications indicated by the core category of *Spontaneous utilisation* (see Figure 4.21c) embody a certain degree of limitation. For instance, although it was found that people initiated conversations with colleagues in front of the Ambient Surfaces, it is hardly possible to precisely determine the content of such conversations other than making some first and more general indications (e.g. informal and formal discussions). Simultaneously, this research does not provide an answer to the question of whether the motivation for such conversations lie in the actual presence of the Ambient Surfaces (i.e. the content shown) or in other aspects (e.g. a colleague is accidentally standing in front of the systems). Similarly, the present research is limited in showing how people changed their way of conducting information work beyond some anecdotal evidence (e.g. utilisation to determine the day up front).

Finally, another limitation stems from the inevitability that the researcher becomes part of the data (Glaser, 1998) hence how, for instance, the author was interacting with staff members throughout observations, the group interview, and the respondent validation affected data collection procedures and, consequently, the data. Glaser (1998) encourages using the motivation of being part of the data but, at the same time, keeping track of this relation. To reflect on this issue, attention is now drawn to limitations of the different data collection methods utilised.

5.5.5.1 Non-Participant Observations

In any kind of participant observation, the greatest threat to conclusions stems from the inevitably prevalence of observer bias (Saunders, Lewis, and Thornhill, 2009). To mitigate the impact of his own perceptions on interpretations, the author critically reflected on his own field notes (e.g. revising documentations by the end of an observation day). However, these field notes depended on the researcher's ability to distinguish between important and trivial aspects hence this level of ability may have affected limitations to some extent. Further limitations stem from the fact that the sitting position allowed people to be observed solely from behind. Another limitation arose from the author's presence time and led to additional interactions with the systems to prepare for providing feedback. To avoid distorting conclusions, identified cases were excluded from analyses.

Finally, while observations were considered complementary to the primary data source (i.e. quantitative interaction data) in *Phase 2* (see Section 4.3), the number of days spent in the field (i.e. 5 days) may also have limited the present study to a lesser or greater extent.

5.5.5.2 Group Interview and Respondent Validation

In semi-structured and in-depth interviews, threats of potential biases come in the form of interviewer bias, interviewee bias, and sampling bias (Saunders, Lewis, and Thornhill, 2009). Interview bias means that the interviewer creates bias through comments, tone, or non-verbal behaviour that affects respondents' answers. In contrast, interviewee bias may originate in the aforesaid but may also emerge through the proactive avoidance of certain topics (e.g. intruding questions on sensitive matters). Finally, time requirements may also have led to bias relating to the sampled population as these may have affected willingness to attend in an interview.

The following steps were undertaken to mitigate these limitations. Firstly, interviewer bias was, amongst others, minimised by carefully preparing the interviews. Maintaining a neutral but not uninterested position during the interviews was also tried. For instance, speaking competitively was avoided and listening intently—in addi-

tion to clearly phrasing questions—was concentrated on. Additionally, audio recordings were respectively created to help focus on the discussions and to minimise the threat of missing certain parts of the interviews in retrospect. Secondly, interviewee bias was mitigated by giving assurance that confidentiality would be maintained. This topic was discussed at the beginning of each interview. Furthermore, the author initially also advised attendees that he was interested in the authenticity of feedback, meaning that both supporting and contradicting results were encouraged. Thirdly, limitations regarding the sampled population were mostly attempted to be mitigated by conducting the interviews on site and by keeping their length to a minimum. In both cases, the selection process was organised internally. The author expressed his desire to include a variety of people representing different roles to reduce limitations related to only including personnel from one particular background. However, the total number of people participating in both interviews limits the scope of the research. While six people participated in the group interview, nine staff members attended the respondent validation.

Lastly, similar to observations, the group interview was also considered a complementary data source in *Phase 2* (see Section 4.3). However, just one group interview was conducted which, in turn, may have also contributed certain limitations.

5.5.5.3 Online Survey

The quality of questionnaires largely depends on the design of questions, its structure, and the rigour of pilot testing (Saunders, Lewis, and Thornhill, 2009). To mitigate limitations, it was collaborated with the *Evaluation, Accreditation, and Quality Management* operation unit from the HAW Hamburg[2] that specialises in conducting survey research. This unit also provided the online survey software that was utilised by respondents to fill in the questionnaire. Prior to a pilot test, questionnaire drafts were discussed with this unit and a pre-pilot test was conducted. The pilot test was then performed and completed by four people. Subsequently, the questionnaire was administered via email, while email addresses were provided by Werum. To avoid potential

[2] https://www.haw-hamburg.de/eqa.html

limitations in responses stemming from concerns of anonymity, the questionnaire's introduction addressed this issue further. It was explained that anonymity was maintained and that it was not possible to pinpoint completed questionnaires to individuals.

Finally, as with the observations and the group interview, the online survey was also meant to complement the existing data sources in *Phase 2* (see Section 4.3). Yet, as only one survey was conducted, this may have also affected the magnitude of limitations.

5.5.5.4 Interaction Data

The utilised primary data source of interaction data embodies further limitations due to its restriction to only pinpoint how (i.e. view events) and when (i.e. touch events) people were utilising the Ambient Surfaces. While this data collection method automatically maintained the anonymity of the individual user, it did not allow topics such as a repeated number of users to be investigated. Furthermore, interaction data shows limitations in indicating unique interaction incidents and the number of people participating in such cases. For example, it is hardly possible to precisely determine how often a system was used throughout an entire week. Also, the number of fingers simultaneously utilised during interactions potentially increased the number of entries in the corresponding logging file. As a result, analyses may have been skewed by apparent misleading peaks in interaction. However, the Ambient Surfaces' user interfaces not required users to use multiple fingers for any interaction hence this issue is arguably small. Individual events such as introducing the systems to external personnel may also have affected latent patterns. Interaction data is further limited with respect to indicating passive utilisation.

The most crucial tool for mitigating limitations in relation to interaction data was to isolate the appearance of the novelty effect. To this end, documentations were consulted and corresponding data was removed from analyses. Limitations were also mitigated by the fact that interaction data from a period of 4 years was incorporated in analyses.

5.6 Summary

The preceding chapter critically reflected on the present research. To this end, it started with a discussion of the methodological approach in Section 5.2, concentrating on the choice of GT methodology and the challenges faced. Section 5.3 then continued with an illustration of this work's main and additional contributions. Prior to a thorough reflection on research limitations in Section 5.5, Section 5.4 revisited the topic of trustworthiness in GT research.

Attention is now drawn to Chapter 6, which indicates research implications, envisions directions for future research, and summarises crucial aspects of the present thesis.

Chapter 6

Conclusion

> "Science never pursues the illusory aim of making its answers final, or even probable. Its advance is, rather, towards an infinite yet attainable aim: that of ever discovering new, deeper, and more general problems, and of subjecting our ever tentative answers to ever renewed and ever more rigorous tests."
>
> —Popper (1959, p. 281)

6.1 Introduction

This chapter concludes this thesis and is organised as follows. It sets out with Section 6.2 that elaborates on research implications. Subsequently, recommendations for future research are introduced (see Section 6.3). The chapter then closes with a summary of this research in Section 6.4 highlighting the most crucial aspects of the present study.

6.2 Research Implications

Findings from this dissertation affect theory (see Section 6.2.1), research (see Section 6.2.2), and practice (see Section 6.2.3) to varying extents. In what follows, these implications are expanded on.

6.2.1 Theory

Theory is foremost affected by this work's substantive theory as it can be considered as one of the few theories of ambient displays in the wild. Apparently, large display research lacks existing general theories as, for instance, indicated in the domain of public displays (Alt et al., 2012). Consequently, the present work arguably puts forth rudimental theoretical insights. This issue is exemplified by a 2016 publication (Schwarzer et al., 2016) which was motivated by the lack of existing long-term experiences with such devices in practice. Also, recent publications in the domain of ambient display research comment on the lack of methodological development (e.g. Hazlewood, Stolterman, and Connelly, 2011; Shelton and Nesbitt, 2017), which in turn exemplifies the lacking number of existing theories and supports the value of the proposed theory.

6.2.2 Research

The research community profits from this work beyond the sheer consideration of its longitudinal findings as it systematically demonstrates practical guidance on how to conduct such research enterprises. To this end, the present research showed the application of GT's two core processes (i.e. constant comparison and theoretical sampling) and contributes a practical systematisation of both to compare and sample quantitative and qualitative data. Ultimately, this work aids researchers in methodologically approaching the challenge of conducting in-situ ambient display research. The relevance for the research community is exemplified by a 2019 publication that introduced the methodological underpinnings of this thesis (Schwarzer et al., 2019). Additionally, the relevance of this research arises from considering a crucial phenomenon in the research design—the novelty effect. A co-authored 2018 publication collated existing knowledge on this effect and presented selected findings from this research (Koch et al., 2018).

6.2.3 Practice

Practice (i.e. particularly ASD practitioners) may also find valuable information in this work. Again, research on large-scale ASD is scarce (Dingsøyr et al., 2018; Rolland, 2016). In this vein, this work unveils somewhat rudimentary insights. Practitioners may find valuable suggestions in considering, for example, how the Ambient Surfaces evolved over time. Also, the importance of direct and indirect communication for ASD teams is corroborated by this thesis (Schwarzer et al., 2017). For instance, the *Confluence* view was utilised as a means to indirectly communicate news articles throughout the entire study. Essentially, however, this thesis proposes that practitioners may find reasonable value in considering ambient media in their own overall information architecture.

6.3 Recommendations for Future Research

This section introduces directions for future research. These suggestions build on the limitations of this research (see Section 6.3.1), its foundations and findings (see Section 6.3.2), as well as gaps identified in the literature (see Section 6.3.3).

6.3.1 Based on Research Limitations

Firstly, the topics of display blindness and of the novelty effect were not the focal point of this research. Longitudinal studies that primarily focus on both effects or one of them would contribute valuable results. Secondly, a further avenue would be to weave in the extant literature to compare it with the proposed theory. Thirdly, the proposed theory conceptually applies to only one specific ASD context and one format of ambient media. Principally, research is warranted that generates its own theories of ambient displays to reach a more profound theoretical understanding of these devices in practice. Finally, researchers are invited to use the data from this thesis to create their own conceptual and theoretical representation to compare it with the theory proposed here. Again, GT is an individually conducted enterprise (Morse et al., 2009) where the researcher becomes an inherent part of the data (Glaser, 1998).

6.3.2 Based on Research Foundations and Findings

Firstly, a promising avenue would be to apply the present work's practical guidance to further similar studies. The goal of such research would be to appraise the applicability of the presented approach. Secondly, the proposed theory could be applied to other operational agile environments (e.g. with a larger or a smaller number of agile teams) to scrutinise how the theory and its elements apply there. The goal would be to increase the level of substantive generality and to ultimately state formal theory. Thirdly, researchers are encouraged to rethink the underpinnings of their own research enterprises when deciding to conduct in-the-wild research. In this regard, the author concurs with the literature (e.g. Bjørn and Boulus-Rødje, 2015) and the reader will hopefully find some valuable means in this work to approach such challenging undertakings. For instance, with the selection of a primary data source, a first stepping stone in this direction is indicated. Fourthly, due to increasing theoretical sensitivity, this research incrementally looked at data through a rather narrowed lens. Therefore, data that was not directly considered may provide fruitful opportunities for future research. For example, suggested recommendations of system improvements were not a direct part of the investigations. Another example is the various emergent research questions that were not addressed in this study. Finally, further directions for future research emerge from investigations of, for instance, how such theories integrate into the overall information architecture of companies. These endeavours would aim at directing the focus towards issues such as cultural concerns (e.g. in terms of information transparency) or how such ambient media holistically integrates in the existing tool landscape.

6.3.3 Based on Research Gaps in the Literature

It is generally encouraged to conduct studies using GT methodology as momentum has yet to be gained in HCI and CSCW research (Muller and Kogan, 2012), but also in the domain of software engineering (Stray, Sjøberg, and Dybå, 2016). An emphasis could be placed, for instance, on the systematisation details regarding both constant comparison and theoretical sampling. Again, both core mechanisms indicate the necessity for further research (Boeije, 2002; Stol, Ralph, and Fitzgerald, 2016). Another

example would be focusing research solely on quantitative data other than secondary survey data. Similarly, more research is warranted considering mixed-methods GT approaches as existing examples are scarce (Jørgensen et al., 2013; Walsh, 2015). Furthermore, Stol, Ralph, and Fitzgerald (2016) suggest research that brings GT's open coding practices to other formats such as diagrams and source code.

However, irrespectively of the selected research methodology, this thesis stresses the general issue that in-the-wild research is highly relevant (Börner, Kalz, and Specht, 2013; Hazlewood, Stolterman, and Connelly, 2011; Nunamaker Jr. et al., 2015; Preim, Ropinski, and Isenberg, 2018; Siek et al., 2014). Consequently, any study with any selected methodology would contribute valuable knowledge to the community.

Finally, large-scale ASD is still an under-researched area (Dingsøyr et al., 2018; Rolland, 2016). Furthermore, existing knowledge on communication in ASD is still scant (Hummel, Rosenkranz, and Holten, 2015). Research which therefore scrutinises the two latter issues would also contribute valuable insights to the respective disciplines.

6.4 Research Summary

This thesis embarks on two crucial research gaps in ambient display research (see Section 2.5). The first research gap (i.e. *Research gap 1*) concerns the limited existing knowledge of ambient media in long-term field deployments. While there is an observable emphasis on studying such devices in academic contexts, their investigation in natural habitats remains an open issue. The second research gap (i.e. *Research gap 2*) concerns the situation that research lacks sufficient methodological advances to guide these enterprises appropriately. This circumstance exemplifies the situation at present that longitudinal studies of ambient displays are rare. Both Chapter 3 and Chapter 4 dealt with these issues in detail. Chapter 3 elaborated on the methodological underpinnings of the present research. It illustrated the various decisions made and motivated why classic GT methodology was applicable for this study. The chapter indicated the methodological building blocks to combine both scientific rigour and the challenging character of in-situ deployments. As a result of choosing classic GT, the research proposes a substantive theory which demonstrates novel insights relating to how ambient

displays are utilised in real-world contexts. Chapter 4 thoroughly described the emergent process of this theory. Driven by constant comparison and theoretical sampling, different data sources were incrementally cross-compared and finally, pinpointed the core category of *Spontaneous utilisation*. Theoretical sensitivity was successively developed to the point where theoretical completeness seemed to be achieved within the limits of the available data. Chapter 5 attempted to critically reflect on the present research, including methodological choices, contributions to existing knowledge, and the limitations of this research.

Considering both the physical characteristics of the ambient display solution used here (see Section 3.4) and the specific research context (see Section 3.3), results of this thesis suggest that these devices are foremost utilised in a spontaneous manner. Fundamentally, such occasions can be characterised as informal rather than planned or scheduled. Two crucial preconditions are: the visibility of information and the fact that someone is walking past the systems. Parsimoniously, the theory is represented by its categories of *Spontaneous utilisation*, *Information visualisation*, and *Passing-by*, which are related to one another. The emergent theory sheds light on each of these categories, their properties, and describes their theoretical relationships in the form of the 30 proposed hypotheses (H_1–H_{30}).

This research arguably puts forth far-reaching insights on ambient displays in the wild. In the grand scheme of things, the present research underlines the relevance of interdisciplinarity to gain new insights. This stance finds support in the growing interest in using GT methodology, for instance, throughout the domains of CSCW and HCI (Muller, 2014), as well as software engineering (Stol, Ralph, and Fitzgerald, 2016). Ultimately, however, longitudinal studies such as this one may prospectively assist in mitigating the scant knowledge on both a findings and methodological level in this domain. To this end, the present study introduces methodological means for other researcher that enable them to embark on novel longitudinal studies of ambient displays in authentic environments.

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Appendix

Appendix A

Digital Libraries Included in *Literature review 2*

The search query was adapted to the varying digital libraries. It was ensured that the query "knowledge sharing AND scrum" was applied consistently. Table A.1 provides an overview of the included libraries, the date of inquiry, the total number of papers obtained, and the number of selected papers. The reading process started on the 18th of August 2016 with a focus on both the ACM Digital Library and the IEEE Xplore Digital Library. On the 29th of August 2016, it was decided to include further libraries in the review process. Papers were selected based on their title and abstract.

Table A.1: Digital libraries incorporated in *Literature review 2*.

Digital libraries	Dates of inquiry	# of papers	# of selected papers
ACM Digital Library[1]	18th August 2016	211	6
IEEE Xplore Digital Library[2]	18th August 2016	189	8
SpringerLink[3]	29th August 2016	200	13
ScienceDirect[4]	29th August 2016	71	4
ProQuest[5]	29th August 2016	12	0
Wiley Online Library[6]	29th August 2016	26	6
Microsoft Academic[7]	29th August 2016	7	0

[1] https://dl.acm.org/
[2] https://ieeexplore.ieee.org/Xplore/home.jsp
[3] https://link.springer.com/
[4] https://www.sciencedirect.com/
[5] https://www.proquest.com/
[6] https://onlinelibrary.wiley.com/
[7] https://academic.microsoft.com/

Appendix B

Data Sources

B.1 Access to Data Sources

This section provides a permalink to a password-protected archive, including all utilised data sources in this work. All material other than the interaction data incorporates coding schemes that were a result of analyses. The data sources are:

- Interaction data log files from the years 2014 to 2017.
- Observations field notes in English.
- The group interview transcript in German.
- The auto-generated online survey report in German.
- The respondent validation transcript in German.

Url: https://users.informatik.haw-hamburg.de/~ubicomp/arbeiten/phd/JS_Data_Sources
Password: "PhDThesisJS2019"

If you feel the need to contact the author personally, please use the following email address: mail@janschwarzer.com.

B.2 Transcription Conventions

Table B.1 shows the conventions that were applied during transcriptions. Some liberties were taken as it was not aimed at linguistic or conversational analyses. Punctuation was used to increase readability, while the following topics were ignored: intonation of

words, word stress, softly or quietly spoken words, emotions used while talking (e.g. speaking whilst laughing), and the stretch of air intakes and extended sounds.

Table B.1: Conventions applied throughout the transcription process.

Codes	Descriptions
[overlap]	Overlapping part in speech (considering the length of the stretch).
(.)	Shorter break ($\leq$ 1 second).
(2.3)	Longer break in seconds ($>$ 1 second).
.h	Audible intake or exhalation of breath (not considering the length of the stretch).
wo:rd	A colon indicates extended sounds (not considering the length of the stretch).
examp--	Two hyphens indicate broken-off words.
(word)	Uncertain transcription.
( )	Incomprehensible part (not considering the length of the stretch).
((comment))	A comment such as laughing noises.
(I: // ... //)	Interviewer signal, while interviewees are speaking.
(Mr/s: // ... //)	Interviewee signal, while others are speaking.
(?: //...//)	Unknown source of signal.
Use cases	Italics, if an interviewee was describing exemplary use cases while speaking.

B.3 Group Interview and Survey Questions (*Phase 2*)

In this section, all questions asked in both the group interview (see Section B.3.1) and the online survey (see Section B.3.2) are provided. To this end, the questions are categorised according to their organisation in the group interview and in the survey.

B.3.1 Group Interview Questions

The interview questions below guided the interviewer throughout the interview but were not answered by interviewees in the illustrated order (i.e. semi-structured interview) due to the course of discussions.

B.3.1.1 Opening Question

- What was your impression of the Ambient Surface system during the previous year?

B.3.1.2 Usage-Related Questions

- Have you and/or your colleagues regularly used the Ambient Surface system (motivation)?
  - If so: Can these regularities, and the situations in which they are used, be described in more detail?
- How many people had access to the system and how many people actually used the system (the majority/a few/specific numbers)?
  - How can these people be characterised (software developers/Scrum Masters/all/repeating users)?
  - How was the system used (groups of people/teams/individuals)?
- Have new routines been established in your daily working life—or in that of your colleagues'—that include the Ambient Surface system?
- Has the system been used in informal or formal group contexts such as meetings (e.g. Daily Scrum and Sprint planning meetings)?
- Have you spoken to colleagues about the system and/or its contents (e.g. "Hey, I saw you doing this or that.")?
- Is the system actively turned on by someone every day? What is the workflow like here?
- Has the QR code been used by you and/or your colleagues?

B.3.1.3 Evaluation Questions

- Do you think the Ambient Surface system is suitable for improving the flow of information in Scrum teams in general? Yes/No? Why?
- Has your awareness of information improved? Are you more aware of what is happening in the team? Yes/No? Why?

B.3.1.4 Touch Events Log File Questions

These questions were discussed in assistance with presentation slides.

- Calendar weeks: Can you explain that (correlation to Sprint Planning meetings/ other events etc.)?
- Times of day: Can you explain that (e.g. lunch breaks/meetings etc.)?
- Weekdays: Why do some days of the week indicate a higher usage?

B.3.1.5 View Events Log File Questions

- After one year of use: Which information view is the most interesting/important for you?
- Would/could you do without one or more information views?

B.3.1.6 Closing Questions

- What leaves a lasting impression? What do you no longer want to miss (e.g. mention one or two properties)?
- Where do you see the development potential of the system? What do you want (e.g. mention a feature/an information view)?
- What have I forgotten to ask or what else would you like to tell me?

B.3.2 Survey Questions

The survey questions below are enriched with additional information in parentheses indicating the type of questions. Furthermore, the following lists of questions use a numerical organisation to better illustrate the different paths through the survey. With the option "not specified" respondents were able to skip questions.

B.3.2.1 Section 1: General Questions

1. Do you use or have you used the Ambient Surface system since its installation in February 2014 (yes/no)?

- If so, respondents proceeded with Question 2 in this section.
- If no, respondents were redirected to Question 15 and subsequently to Section 5.

2. Which regularity best describes the nature of your use of the Ambient Surface system (single choice)?
   - Daily
   - Weekly
   - Monthly
   - Less often
   - Not specified
3. What is your motivation to use the Ambient Surface system (multiple choice)?
   - I see what my colleagues are doing
   - Colleagues can see what I do
   - I can get information quickly (e.g. after lunch)
   - I get a first, rough idea
   - I exchange information more often with colleagues
   - Other
   - Not specified
4. How intuitive do you think the use of the Ambient Surface system is (6-point Likert scale, ranging from *very intuitive* to *not intuitive at all*)?
5. How suitable do you think the Ambient Surface system is for presenting additional information from your team/other teams on another medium in addition to conventional end devices such as PCs, smartphones, and tablets (6-point Likert scale, ranging from *very suitable* to *not suitable at all*)?
6. Can you describe where you see problems (open-ended)?

7. How appealing do you think the design of the user interface is (6-point Likert scale, ranging from *very appealing* to *not appealing at all*)?

8. What do you find less attractive/not so appealing about the user interface (open-ended)?

9. Where do you see the strengths of the Ambient Surface system (multiple choice)?

    - I see what is happening in the department
    - I can obtain information away from my desktop computer
    - Transparency is created
    - Conversations are encouraged
    - Meetings are technically supported
    - Other—If selected: What exactly would these strengths be (open-ended)?
    - Not specified

10. Where do you see the weaknesses of the Ambient Surface system (multiple choice)?

    - The information is not sufficient
    - There is too much information
    - Important information is not visible
    - The user interface is not designed attractively enough
    - The daily work is not meaningfully supported
    - Other—If selected: What weaknesses are these exactly (open-ended)?
    - Not specified

11. In your opinion, what could be better solved regarding the Ambient Surface system (open-ended)?

12. Which property/function of the Ambient Surface system leaves a lasting impression on you (open-ended)?

13. Based on your own experience with the Ambient Surface system, what would you no longer want to miss out on in your daily work? (open-ended)?

14. What other feature/function should the Ambient Surface system support (open-ended)?

15. Please let us know briefly why you did not use the Ambient Surface system (multiple choice).

    - The information provided was insufficient
    - I prefer to get my information from the PC
    - For me the format is not appealing
    - I feel watched during use
    - I am missing a desktop/tablet/smartphone variant
    - Other—If selected: Can you explain these reasons in more detail (open-ended)?
    - Not specified

16. What would have to change in the Ambient Surface system for you to use it (open-ended)?

B.3.2.2 Section 2: Information Views

In this section, respondents were asked to provide their options regarding the information views *Jenkins*, *Team Charts*, *Test Suites*, and *Confluence*. As the questions were the same for each of these views, they are exemplarily indicated only once for the *Jenkins* view.

1. Did you use the *Jenkins* view (yes/no/not specified)?

    - If so, respondents proceeded with Question 2.
    - If no, respondents were redirected to Question 7.
    - If not specified, respondents continued with same questions for the next information view.

2. How understandable do you think the information in the *Jenkins* view is (6-point Likert scale, ranging from *very understandable* to *not understandable at all*)?

3. From your point of view, where were the problems of understanding (open-ended)?
4. How useful do you think the *Jenkins* view is (6-point Likert scale, ranging from *very useful* to *not useful at all*)?
5. What do you find less/not useful (open-ended)?
6. Did you miss any information in the *Jenkins* view (yes/no/not specified)?
    - If so: Please briefly describe what you have been missing (open-ended).
7. Why did you not use the *Jenkins* view (open-ended)?

B.3.2.3 Section 3: Information Flow in the Department

1. Does the Ambient Surface system increase the visibility of information (yes/no/not specified)?
    - If so: Why does the Ambient Surface system increase the visibility of information (open-ended)?
    - If no: Why does the Ambient Surface system not increase the visibility of information (open-ended)?
2. Does the Ambient Surface system ease access to information (yes/no/not specified)?
    - If so: Why is access to information easier (open-ended)?
    - If no: Why is access to information not easier (open-ended)?
3. To what extent does the following statement apply to you: By using the Ambient Surface system, I have a better overview of what is happening in my team (6-point Likert scale, ranging from *wholeheartedly applies* to *does not apply at all*).
    - Why is this less, or not, true for you (open-ended)?
4. To what extent does the following statement apply to you: By using the Ambient Surface system, I keep a better overview of what is happening in other teams (6-point Likert scale, ranging from *wholeheartedly applies* to *does not apply at all*).

- Why is this less, or not, true for you (open-ended)?

5. To what extent does the following statement apply to you: I have perceived information through the system that might otherwise have remained hidden from me (6-point Likert scale, ranging from *wholeheartedly applies* to *does not apply at all*).

   - Why is this less, or not, true for you (open-ended)?
   - Can you give one or more examples (open-ended)?

6. How high (i.e. in percent) do you estimate the share of informal exchange (e.g. ad-hoc discussions, spontaneous meetings) with your colleagues in your daily working time (single choice)?

   - 0–10%
   - 11–20%
   - 21–30%
   - 31–40%
   - 41–50%
   - 51–60%
   - 61–70%
   - 71–80%
   - 81–90%
   - 91–100%
   - Not specified

7. How high (i.e. in percent) do you estimate the share of formal exchange (e.g. meetings, e-mails, chats, telephone calls) with your colleagues in your daily working time (single choice)?

   - 0–10%
   - 11–20%

- 21–30%
- 31–40%
- 41–50%
- 51–60%
- 61–70%
- 71–80%
- 81–90%
- 91–100%
- Not specified

B.3.2.4 Section 4: The Ambient Surfaces System in Everyday Working Life

1. Has the way you obtain information changed for you as a result of using the Ambient Surface system (yes/no/not specified)?
   - If so: How has your information gathering changed (open-ended)?
2. In your opinion, has the way in which your team/the teams obtain information changed as a result of using the Ambient Surface system (yes/no/not specified)?
   - If so: How has the information gathering of your team/the teams changed (open-ended)?
3. Have you been able to observe conversations in front of the Ambient Surface system (yes/no/not specified)?
   - If so: What was the nature of the conversations (multiple choice)?
     - Spontaneous (e.g. lunch break)
     - Planned (e.g. meetings)
     - Informal (e.g. ad-hoc meetings)
     - Formal (e.g. Daily Scrum meeting)
     - Other

  - Not specified

- As well as: How many people were involved in the conversations (multiple choice)?
  - 2 persons
  - 3 persons
  - 4 persons
  - 5 persons
  - More than 5 persons
  - Not specified

4. Were you the initiator of a conversation in front of the Ambient Surface system (yes/no/not specified)?
5. Have you participated in such conversations in front of the Ambient Surface system as a participant (yes/no/not specified)?
6. Have you approached people from your own team because you have previously perceived information on the system (yes/no/not specified)?
7. Have you approached people from other teams because you have previously perceived information on the system (yes/no/not specified)?
8. Have you been approached by people from your team based on visible information on the system (yes/no/not specified)?
9. Have you been approached by people from other teams based on visible information on the system (yes/no/not specified)?
10. In which situations was the Ambient Surface system used (multiple choice)?
    - Before, during, or after the breakfast break
    - Before, during, or after the lunch break
    - Before or after a meeting
    - During a meeting

- When printing
- When fetching drinks
- Other—If selected: Could you please briefly mention these situations (open-ended)?
- Not specified

11. Do you agree with the following statement: The use of the Ambient Surface system is primarily of a spontaneous nature (yes/no/cannot tell/not specified).
12. Do factors such as increased workload influence the frequency of use of the Ambient Surface system (yes/no/not specified)?
13. Did you find it annoying when information you generated (e.g. errors in the *Jenkins* view) became visible on the Ambient Surface system (yes/no/does not apply/not specified)?

B.3.2.5 Section 5: Personal Details

1. Which age group do you belong to in years (single choice)?
   - Younger than 21
   - 21–30
   - 31–40
   - 41–50
   - 51–60
   - Older than 60
   - Not specified
2. What is your gender (single choice)?
   - Female
   - Male
   - Other

- Not specified

3. What role do you have in your company (multiple choice)?

   - Scrum Master
   - Product Owner
   - Software developer
   - Team leader
   - Head of department
   - Administrator
   - Other—If selected: Please tell us briefly what your role is (open-ended).
   - Not specified

4. In years, how long have you been working in your company (single choice)?

   - Less than a year
   - 1–2
   - 3–5
   - 6–10
   - 11–20
   - More than 20 years
   - Not specified

5. What is your highest vocational qualification (single choice)?

   - Master
   - Bachelor
   - Diploma
   - Vocational training
   - Other
   - Not specified

6. In which subject did you obtain your highest vocational qualification (open-ended)?

B.3.2.6 Section 6: Closing Question

1. Is there anything else you would like to tell us in conclusion (open-ended)?

Appendix C

Hardware Components and User Interface Screenshots

C.1 Mac mini MC438LL/A

Table C.1: Selected components of the Mac mini MC438LL/A.

Categories	Components
Processor	2.66 GHz Intel Core 2 Duo (P8800)
Memory	4 GB of 1,066 MHz DDR3
Graphics	NVIDIA GeForce 320M (dedicated)
Storage	2x 500 GB HDD SATA-II 7,200 RPM
Operating system	Microsoft Windows 7

C.2 Fujitsu Esprimo Q910

Table C.2: Selected components of the Fujitsu Esprimo Q910.

Categories	Components
Processor	2.90 GHz Intel Core i5-3470T
Memory	4 GB of 1,600 MHz DDR3
Graphics	Intel HD Graphics (integrated)
Storage	1x 500 GB HDD SATA-II 5,400 RPM
Operating system	Microsoft Windows 7

C.3 Information Views and Features

C.3.1 *Jira* View

This custom view (see Figure C.1) visualised recent activities from the Jira system which were provided by its REST API (e.g. editing tasks and subtasks). The following provides translations for the German text in the figure:

- The highlighted message in blue at the top: "20.04.2015: Hello Werum! Issue status information is now visible in the Test Suites Overview and Confluence."
- The label "Letzte Änderung vor über ..." corresponds to "Latest update ... ago", whereas "Tage" or "Tagen" (the plural form of "Tage") correspondingly means "day" or "days".
- The label "... änderte den Wert von ..." corresponds to "... changed the value of ...".
- The button labelled "Mehr" means "More".
- The label "JETZT" means "NOW".

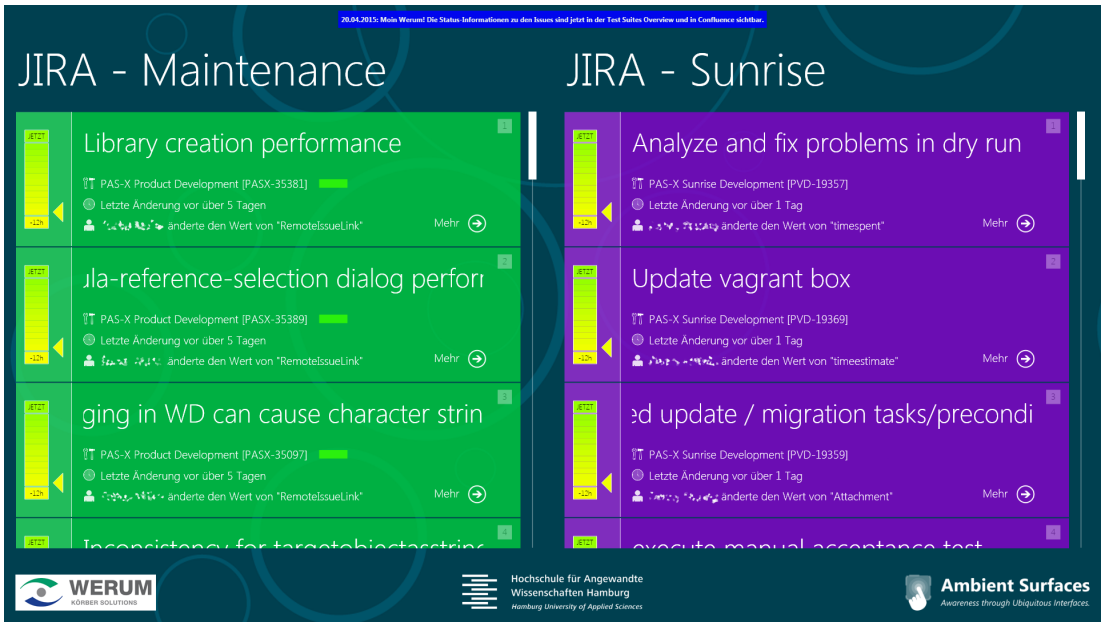


Figure C.1: The *Jira* view as of 2015.

C.3.2 *Jenkins* and *GoCD* View

Like the *Jira* view, the *Jenkins* view (see Figure C.2) was fully custom-made and utilised the correspondent Jenkins REST API. The view presented selected project build statuses from the Jenkins environment on the screens. The *GoCD* view (also see Figure C.2) visualised selected information regarding the continuous delivery process. The following provides translations for the German text in the figure:

- The highlighted message in yellow at the top: "08.08.2017: Hello Werum! Brief Info: As of today and until further notice, no further data will be gathered with the Kinect cameras."
- The labelled button "App Neustart" corresponds to "App Restart". This translation is not repeatedly mentioned in the remainder of the appendix.
- The clock in the upper right corner could potentially display "Mo", "Di", "Mi", "Do", "Fr", "Sa", and "So", which indicates weekdays ranging from Monday (i.e. "Mo") to Sunday (i.e. "So"). These translations are also not repeatedly mentioned below.
- The label "... Jobs in Arbeit" means "... Jobs in progress".
- The word "fehlerhaft" corresponds to "corrupted".
- The word "stabil" means "stable", whereas "instabil" translates to the opposite "unstable".

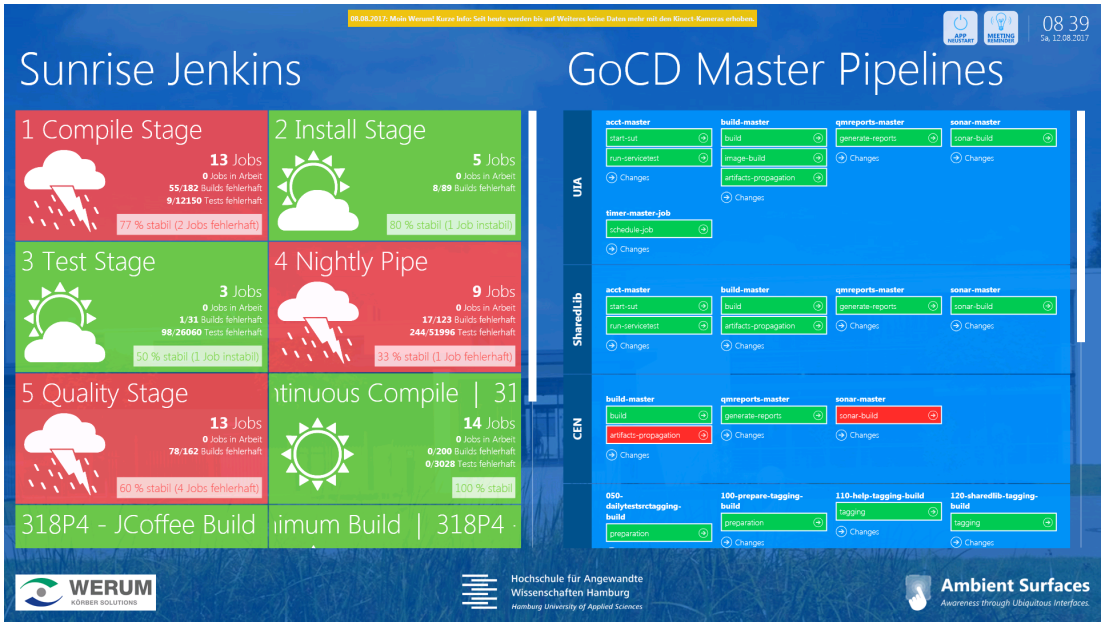


Figure C.2: The *Jenkins* view (left) and the *GoCD* view (right) as of 2017.

C.3.3 *Team Charts* View

This view (see Figure C.3) displayed team charts from the Jira environment. In the figure, only a little German is used:

- The highlighted message in red at the top translates to: "07.04.2017: Hello Werum! In addition to the Team Charts, the PAS-X Bug Survey Charts are also now available (accessible via a new button on the left-hand side)."

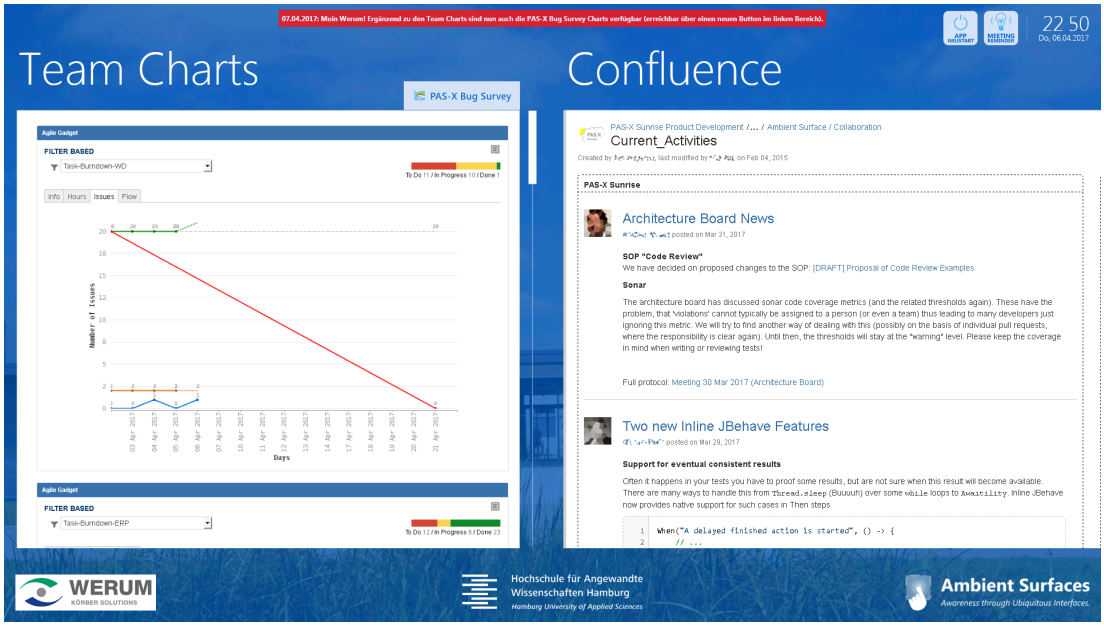


Figure C.3: The *Team Charts* view (left) as of 2017.

C.3.4 *Confluence* View

The *Confluence* view (see Figure C.4) provided news such as department, architectural, and product announcements. It is worth a special mention that this view was the only one that relied heavily on proactive user participation in terms of content generation. The German texts embedded in the figure are equal to texts in the *Team Charts* view (see Section C.3.3).

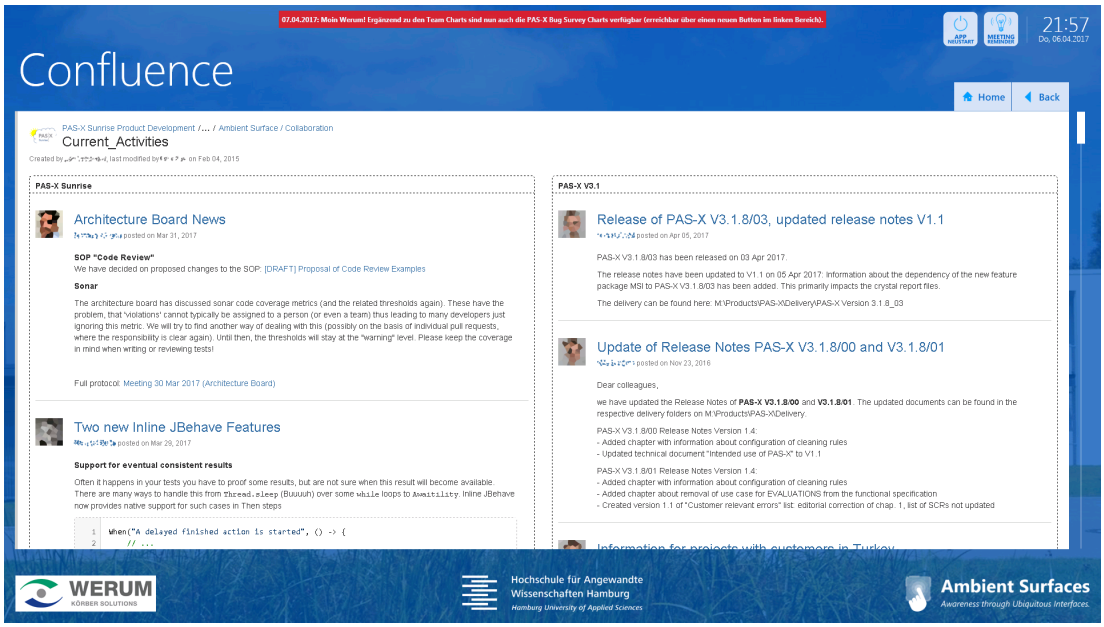


Figure C.4: The *Confluence* view as of 2017.

C.3.5 *Test Suites* View

The *Test Suites* view (see Figure C.5) built on the custom Tetris tool. Test suites, statuses of test runs, and correspondent team responsibilities were visualised. In the figure, only a little use of German is again present. The highlighted message in yellow at the top corresponds to the message in the *Jenkins* view and *GoCD* view (see Section C.3.2).

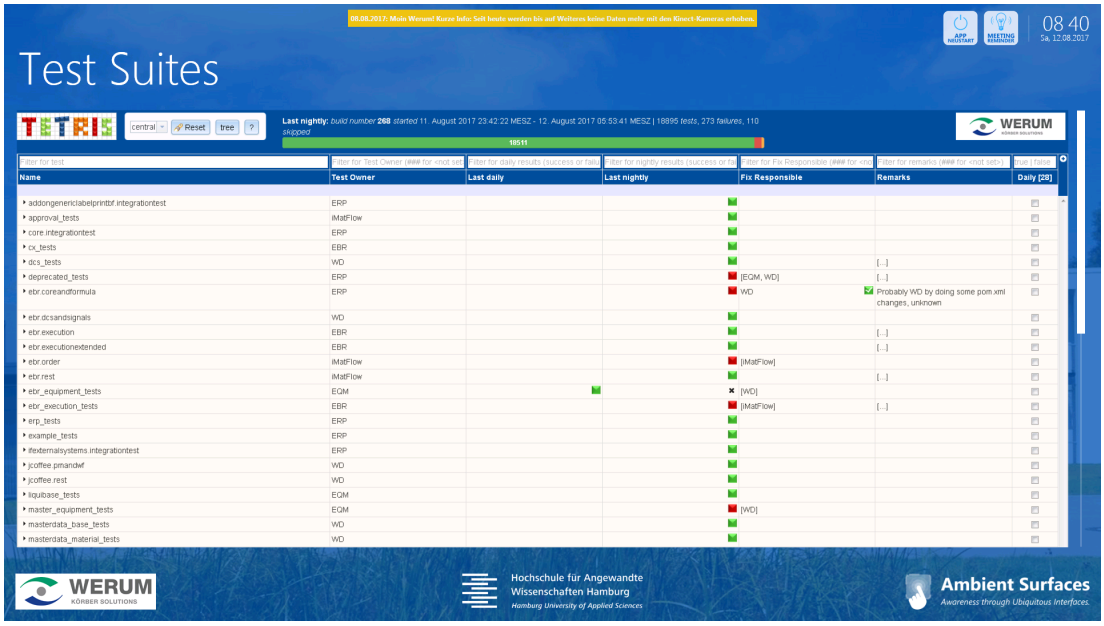


Figure C.5: The *Test Suites* view as of 2017.

C.3.6 *Bug Survey* View

Contrary to the *Team Charts* view, the *Bug Survey* view (see Figure C.6) displayed burn up charts that showed created and resolved bugs in comparison for selected product versions. Only a little German is utilised in this visualisation. The highlighted message in red at the top is equal to the message in the *Confluence* view (see Section C.3.4).

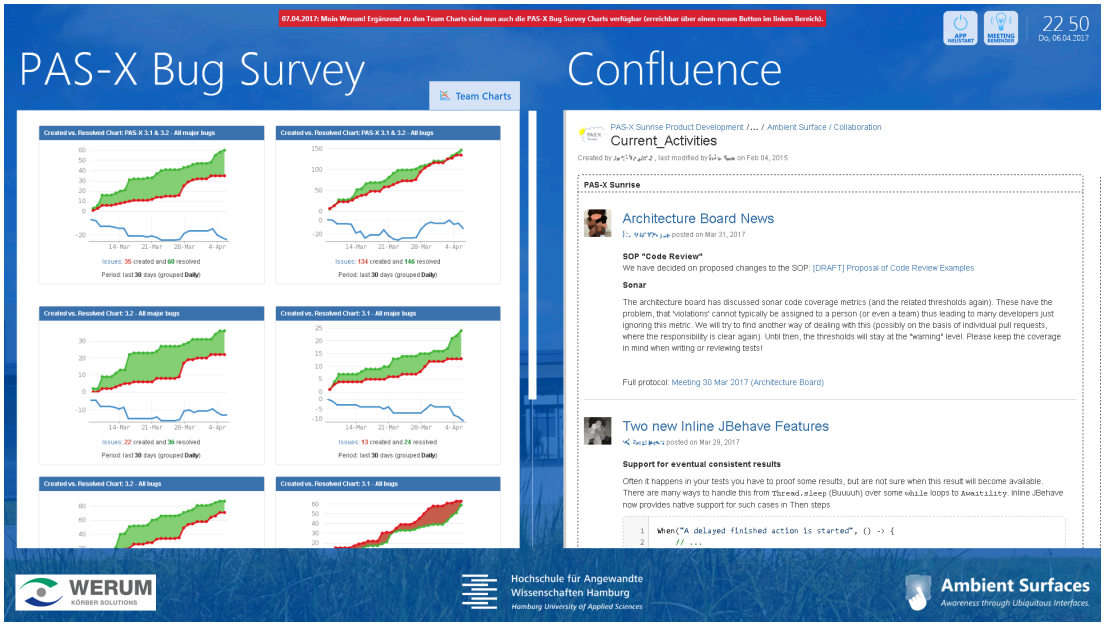


Figure C.6: The *Bug Survey* view (left) as of 2017.

C.3.7 *Meeting Reminder* Feature

The *Meeting Reminder* feature (see Figure C.7) enabled staff members to notify colleagues via email (e.g. when colleagues were late for a meeting). The view was accessible via a button in the upper right corner of the screens. The translations for the figure are:

- The button label “Alle” means “All”.
- The button label “Leer” translates to “Empty”.
- The label “Emfpänger/innen:” corresponds to “Recipients:”.
- The label “Gruppe(n):” equates to “Group(s):”.
- The button label “Als neue Gruppe speichern” means “Save as a new group”.
- The button label “Gruppe löschen” translates to “Delete group”.
- The label “Art” corresponds to “Type” (i.e. the type of a meeting), whereas the option “Anderes Meeting” translates to “Other meeting”.
- The label “Zeitpunkt” means “Point in time”, whereas the option “Anderer Zeitpunkt” equates to “Another point in time”.

- The label “Zusatz” translates to “Addition”.
- The label “Ort” equates to “Location”, whereas the option “Anderer Raum” corresponds to “Other room”.
- Finally, the two buttons “Senden” and “Schließen” respectively translate to “Send” and “Close”.

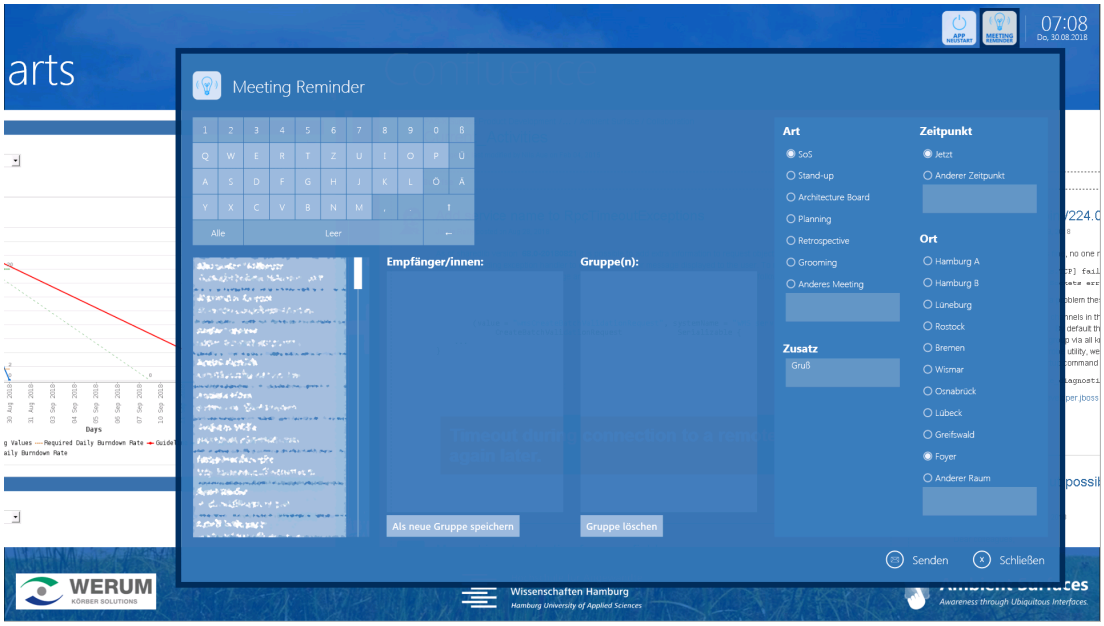


Figure C.7: The *Meeting Reminder* feature as of 2018.

C.3.8 *Sharing* Feature

Like the *Meeting Reminder* feature, the *Sharing* feature (see Figure C.8) was intended to remind of or point to information via email notifications. This feature was available in the views *Jira*, *Jenkins*, *Team Charts* (i.e. prior to its revision in 2016), and *GoCD*. The translations for the figure are as follows:

- The label “Teilen” means “Share”.
- Again, the buttons “Senden” and “Schließen” respectively translate to “Send” and “Close”.
- The label “Alle”, again, means “All”.

- The bold labelled text below the “Senden” and “Schließen” buttons translates to “To whom should this cue be sent? Please select person(s) on the left.”

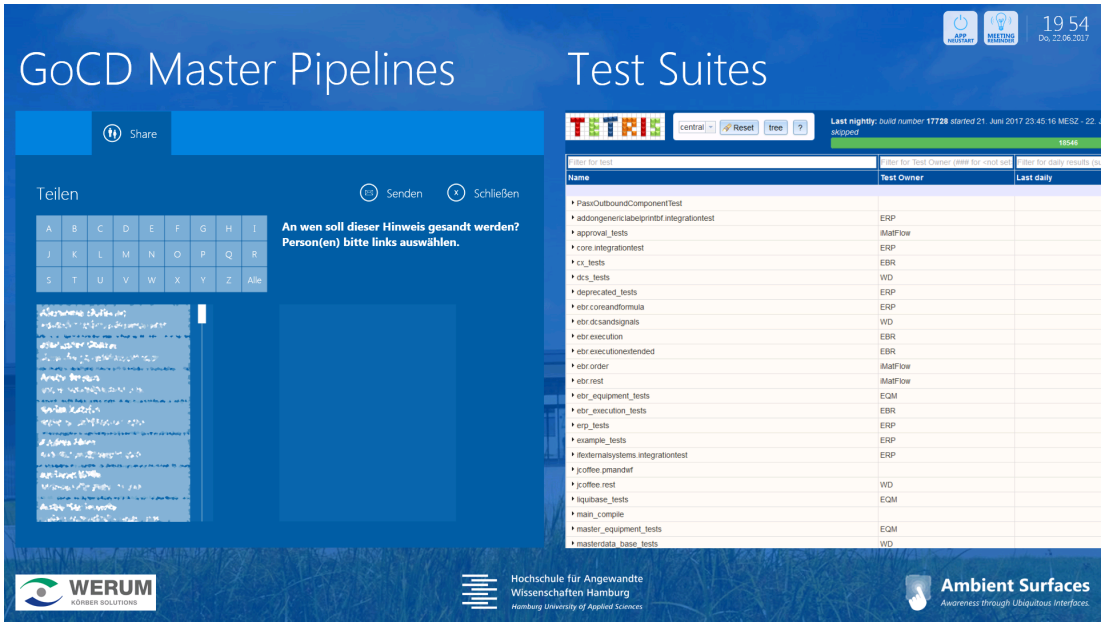


Figure C.8: The *Sharing* feature (left) as of 2017.

Appendix D

Ethics Approval and Consent Form

D.1 Ethics Approval (Email Correspondence Extract)

From: Malcolm Crowe <Malcolm.Crowe@uws.ac.uk>
Sent: 30 March 2017 10:02
To: Jan Schwarzer <jan.schwarzer@haw-hamburg.de>
Cc: Irene Edmiston <Irene.Edmiston@uws.ac.uk>, Qi Wang <Qi.Wang@uws.ac.uk>
Subject: RE: Fwd: PhD Student Project's Ethics Form

Jan,
All this sounds more than sufficient, and your supervisors can approve such details on our behalf.
I will attach this content and image to your proposal and upload it as approved.
Best wishes
Malcolm Crowe

From: Jan Schwarzer [mailto:jan.schwarzer@haw-hamburg.de]
Sent: 30 March 2017 08:52
To: Malcolm Crowe <Malcolm.Crowe@uws.ac.uk>
Cc: Qi Wang <Qi.Wang@uws.ac.uk>
Subject: Re: Fwd: PhD Student Project's Ethics Form

Hi Malcolm,

I've talked to both my HAW and UWS supervisors and I would like to propose the following.

Based on the present participant information sheet and consent form, I will prepare a new consent form and will send it to the company to sign it (e.g., the head of department). In this document, I will list and explain all utilized methods (i.e., a group interview, an online survey, observations, logging and cameras) and that I briefed the company (e.g., in case of the cameras the worker's council) accordingly every time prior to data collection. Furthermore, the document will include statements that I can use results in publications and that all data in my research is anonymized. For future data collection efforts (if necessary), I will prepare a new consent form accordingly.

I think that such a form would be more sufficient than some informal emails which I translate from German to English language. In addition, the head of department is the person who initiated the ongoing cooperation between the HAW and the company in the first place.

Would do you think of my proposal? Would this be in line with the UWS ethics standards? I must say, this process will most likely take a couple of weeks (i.e., signing process, document creation, etc.) Currently, I am in the middle of preparing my transfer event which is at the end of April.

P.S. A "small notice nearby" (see attachment) already exists (seven pages in German language). It explains camera specifications, in short the research's methodology approach, data being collected with the camera and what I will do with the data. If you need a translated version of this document as well, please let me know.

Regards
Jan

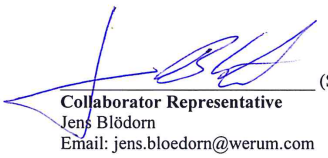
D.2 Signed Ethics Consent Form

Ethics Consent Form

Title of the Study:	Spontaneous Utilisation: A Classic Grounded Theory of Utilising Ambient Displays in Authentic, Co-located, Matured, and Large-scale Agile Software Development Environments
Principal Investigator:	Jan Schwarzer
Collaborator:	Werum IT Solutions GmbH, represented by Jens Blödorn (Senior Head of PAS-X Development)
Director of Studies:	Qi Wang

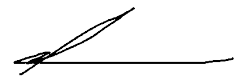
Please tick each box as applicable:

1. I confirm that I am entitled to speak on behalf of the staff and that I oversaw the project in question.	☑
2. I confirm that we the staff and I agreed to participate in the study.	☑
3. I confirm that we had been informed about the purpose of the study to our satisfaction and that we had been given the opportunity to ask questions and raise concerns.	☑
4. I confirm that we had been consulted prior to any data collection activities and that we had the opportunity to ask questions and to raise concerns. Wherever required, the works council was internally incorporated into such processes.	☑
5. I consent to the use of anonymised results from this study in scientific publications (e.g. conference papers and journal articles) and less-rigour fora (e.g. university presentations).	☑
6. I consent to the disclosure of the company's name 'Werum IT Solutions GmbH' in the context of the PhD thesis, scientific publications, and less-rigour formats (e.g. university presentations).	☒
7. I understand that our participation was voluntary and that we were free to withdraw at any time.	☒



(Signature) 17.06.19 (Date)

Collaborator Representative
Jens Blödorn
Email: jens.bloedorn@werum.com



(Signature) 20.06.2019 (Date)

Principal Investigator
Jan Schwarzer
Email: jan.schwarzer@haw-hamburg.de

Appendix E

English-German Translations of Utilised In-Text Quotations

Table E.1 lists translated passages that were used in the main document. In the translations below, speech disfluencies from the original language (i.e. German) were ignored. It is also to be remembered that ellipses were maintained in quotations on chapter introduction pages.

Table E.1: Used in-text quotations from staff members.

In-text quotations	**Original German texts**
"... I used it [the first Ambient Surface] as well. However, not regularly, but actually more in spontaneous occasions when I walk past it." (p. 82)	"... ich habe es auch genutzt. ä:h Allerdings nicht regelmäßig, sondern: ä:h eigentlich eher zu spontanen Anlässen, wenn ich dran vorbeigehe." (Group interview)
"However, not regularly, but actually more in spontaneous occasions when I walk past it." (p. 109)	"Allerdings nicht regelmäßig, sondern: ä:h eigentlich eher zu spontanen Anlässen, wenn ich dran vorbeigehe." (Group interview)
"when there are things which you are not interested in, then you pass by." (p. 110)	"wenn grade die Sachen dastehen, die einen nicht interessieren, dann geht man vorbei." (Group interview)
"Having information about all teams simultaneously at one location often encourages spontaneous discussions among colleagues. This fosters the exchange or informs many about the work of others." (p. 113)	"Dass man Informationen über alle Teams an einem Ort nebeneinander hat, regt häufig sponntan Diskussionen unter Kollegen an. Das fordert den Austausch bzw Informiert viele über die Arbeit anderer. " (Online survey)
"The good overview. Everything at a glance and virtually while passing by." (p. 114)	"Die gute Übersicht. Alles auf einen Blick und das quasi im Vorbeigehen." (Online survey)
"Because on the way to the kitchen they are visible as I pass by without having to do anything." (p. 114)	"Weil sie auf dem Weg zur Küche im Vorbeigehen sichtbar sind ohne dass ich etwas tun muss." (Online survey)
"Information can be retrieved during coffee breaks meaning the normal workflow on the PC is less disturbed." (pp. 114–115)	"Informationen können bei Kaffeepausen nebenbei abgeholt werden und somit wird der normale Aarbeitsfluss am PC weniger gestört." (Online survey)
"I get information that can be seen on the Ambient Surface system by walking past it and no longer look for it in the workplace." (p. 115)	"Informationen die auf dem Ambient Surface System zu sehen sind hole ich mir im vorbeigehen dort und suche nicht mehr am Arbeitsplatz danach." (Online survey)

Appendix F

Lists of Proposed Hypotheses and Emergent Questions

F.1 Proposed Hypotheses (H_1–H_{30})

This section lists all hypotheses proposed in this research (i.e. *Phase 1* to *Phase 4*). To assist in relating these hypotheses, they are thematically categorised below.

F.1.1 *Phase 1* (Hypotheses H_1–H_7)

Times of day:

- H_1: The Ambient Surface is notably utilised in the early morning when people are arriving at work. (p. 85)
- H_2: The Ambient Surface is mostly utilised when people are going to or are returning from lunch. (p. 85)
- H_3: The Ambient Surface is notably utilised in the late afternoon when people are leaving work. (p. 85)
- H_4: There are times of day in which the use of the Ambient Surface notably decreases. (p. 85)

The novelty effect:

- H_5 (reformulated) : A novelty effect results in the usage of the Ambient Surface which distracts from latent patterns due to the magnitude of interactions and the time of their occurrence. (p. 91)
- H_6: Changes to an existing system contribute towards or extend a prevalent novelty effect. (p. 87)

Contribution factors:

- H_7: The Ambient Surface provides positive contributing factors beyond a prevalent novelty effect. (p. 89)

F.1.2 *Phase 2* (Hypotheses H_8–H_{21})

Times of day:

- H_8: The Ambient Surface is notably utilised beyond lunch time, depending on the number of passers-by, which leads to correspondent increases and decreases in utilisations throughout a day. (p. 106)

Individual and group usage:

- H_9: Individual use outnumbers group usage. (p. 106)
- H_{16}: Times of day affect the ratio of passers-by in terms of individual users and group usage. (p. 111)
- H_{17}: Individual preferences affect incidents of spontaneous utilisation. (p. 111)
- H_{19}: Personal information work preferences affect the general attitude towards the Ambient Surfaces while passing by. (p. 114)

Awareness:

- H_{10}: The Ambient Surface is most notably leveraged to increase one's individual awareness of information. (p. 106)

- H_{18}: The creation of inter-team awareness outweighs the creation of intra-team awareness. (p. 112)

Types of utilisation:

- H_{11}: Active usage outlasts its passive counterpart. (p. 106)
- H_{12}: Passive usage outnumbers its active counterpart. (p. 106)
- H_{13}: *Type 3* utilisation incidents outnumber those of *Type 2*. (p. 107)
- H_{14}: *Type 2* utilisation incidents outlast those of *Type 3*. (p. 107)
- H_{15}: Types of utilisation may occur in combination. (p. 107)

Communication:

- H_{20}: The creation of subsequent intra-team communication outweighs the creation of subsequent inter-team communication. (p. 114)

The honey-pot effect:

- H_{21}: People standing in front of the Ambient Surfaces attract other potential users. (p. 114)

F.1.3 *Phase 3* (Hypotheses H_{22}–H_{26})

Design-related issues:

- H_{22}: The design complexity of information views affects the total number of utilisations (i.e. *Type 1*). (p. 123)
- H_{23}: The efforts to unveil an information view affect the total number of utilisations (i.e. *Type 1*). (p. 123)

Content relevance:

- H_{24}: Utilisation behaviour changes as the relevance of content changes. (p. 123)
- H_{25} (reformulated): Content relevance depends on temporal attributes such as times of day and current activities in the department. (p. 135)

External factors:

- H_{26}: External factors such as different location setups affect the patterns of passers-by. (p. 126)

F.1.4 *Phase 4* (Hypotheses H_{27}–H_{30})

Type of audience:

- H_{27}: Times of day affect the type of audience that is passing by the Ambient Surfaces. (p. 134)

Display blindness:

- H_{28}: Repeatedly provoking the novelty effect mitigates the prevalence of display blindness. (p. 135)

Passers-by:

- H_{29}: System vacancy affects the decision-making process to further engage while someone is passing by. (p. 136)
- H_{30}: Peoples' facing position while passing by affects the general notion to further engage. (p. 136)

F.2 Emergent Questions (Q_1–Q_{19})

The following indicates the varying questions that emerged throughout analyses (i.e. *Phase 1* to *Phase 3*). While question Q_3 (*Phase 1*) reflects the main driver for data collection and analysis activities in *Phase 2*, question Q_{10} (*Phase 2*) portrays the focus in *Phase 3*.

F.2.1 *Phase 1* (Questions Q_1–Q_6)

- Q_1: What positive contributing factors does the Ambient Surface promote? (p. 97)

- Q_2: What are the reasons for the varying reductions in interactions throughout a day? (p. 97)
- Q_3: How is the Ambient Surface passively being utilised by staff members? (p. 97)
- Q_4: How do the relationships between variables in Figure 4.7 change when they are incrementally compared to additional interaction data? (p. 97)
- Q_5: What can be learnt with respect to display blindness by utilising further data collection techniques? (p. 97)
- Q_6: How do the conclusions regarding data saturation change when they are compared to additional interaction data from subsequent years? (p. 97)

F.2.2 *Phase 2* (Questions Q_7–Q_{14})

- Q_7: How do the identified three types of utilisation occur in combination? (p. 115)
- Q_8: How does the result of processing information relevance affect subsequent activities? (p. 115)
- Q_9: What characteristics show candidates of deliberate utilisation? (p. 116)
- Q_{10}: How are the varying information views utilised? (p. 116)
- Q_{11}: How is individual information work affected? (p. 116)
- Q_{12}: How frequently do incidents of direct communication occur subsequently to spontaneous utilisation incidents? (p. 116)
- Q_{13}: What is the content of subsequent indirect communication incidents? (p. 116)
- Q_{14}: How distinctive is individual usage when considering a large number of users? (p. 116)

F.2.3 *Phase 3* (Questions Q_{15}–Q_{19})

- Q_{15}: How are the processes of intentionally searching for desired information and of exploring content out of sheer curiosity different from each other? (p. 130)
- Q_{16}: How do interactions related to the processes of intentionally searching for desired information and of curiously exploring content affect utilisation (i.e. in terms of the total number and the way of utilisation)? (p. 130)
- Q_{17}: What are the reasons for the varying levels of content relevance throughout a working day? (p. 131)
- Q_{18}: Do the presented statistically significant similarities in interaction data in 2014 and 2015 reoccur in other samples? (p. 131)
- Q_{19}: What are the potential metrics to identify the most relevant content? (p. 131)