Immersive Technologies and Organizational Routines

When Head-mounted Displays meet Organizational Routines

Hofma, Christian Casper

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WHEN HEAD-MOUNTED DISPLAYS MEET ORGANIZATIONAL ROUTINES

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PhD Series 31.2020

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When head-mounted displays meet organizational routines

Author

Christian Casper Hofma

Copenhagen Business School, Frederiksberg, DK, cch.digi@cbs.dk

Primary supervisor

Ioanna Constantiou, Professor

Copenhagen Business School, Frederiksberg, DK, ic.digi@cbs.dk

Secondary supervisor

Mads Bødker, Associate Professor

Copenhagen Business School, Frederiksberg, DK, mb.digi@cbs.dk

Department of Digitalization

Doctoral School of Business and Management

Copenhagen Business School

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English abstract

Immersive technologies, like head-mounted displays, have increasingly been gaining traction in the entertainment industry. However, despite the benefits that head-mounted displays have in professional settings, like the architect, engineering and construction (AEC) industry, they are not widely adopted and used in these settings. To better understand why this thesis investigates head-mounted displays, in the context of the AEC industry by stating the following research question: *"How does the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines?"* I answer the research question by employing insights from organizational routines and the imbrication lens. I conducted five exploratory interviews with companies within the AEC industry. I later complemented these interviews with an in-depth longitudinal case study in an architect office. The longitudinal case study comprises of six months of observational data, 19 interviews, and 150 documents and design artifacts. This thesis contributes to IS research on immersive technologies, organizational routines, and lastly to practice. First, I contribute to research on immersive technologies by attending to the relational and emergent characteristics of immersion. Second, I show that head-mounted displays ability to shut users off from the surrounding environment, can be an obstacle for organizations when enrolling it into their organizational routines. I contribute to organizational routines research in the following ways. First, I show how the imbrication lens and organizational routines theory can be combined to better understand how the materiality of immersive technologies changes organizational routines. Second, by introducing the imbrication lens to organizational routines research I maintain a distinction between what a technology is and what it does together with humans, when these two entities imbricate. This allows me to directly conceptualize the technology's materiality including its flexibility and inflexibility. I thus provide a way to understand the role that materiality plays when investigating why immersive technologies sometimes matter a great deal; at other times, they do less to influence organizational routines. Third, I show how immersive technologies can create variations across organizational routines, reiterating the importance of moving beyond organizational routines as the unit of analysis. Fourth, I lay the foundation for a deeper integration between the organizational routines theory and the imbrications lens. I contribute to practice by showing how and when companies in the AEC industry can use immersive technologies to improve collaboration with stakeholders, professionals and laymen alike, during the design phase of building projects, potentially alleviating some of the productivity issues of the industry.

Dansk resumé

Fordybende teknologier, som hovedmonterede skærme, er i stigende grad blevet populære indenfor især underholdningsindustrien. På trods af de fordele, som hovedmonterede skærme kan have i arbejdsrelaterede sammenhænge, som arkitekt-, ingeniør- og entreprisebranchen (AIE), er de ikke bredt adopteret eller brugt i denne branche. Det er på trods af de positive effekter, som fordybende teknologier tidligere har haft på branchen. For bedre at forstå hvorfor, undersøger denne afhandling: *Hvordan imbricerer (imbricate) fordybende teknologiers materie og form, som f.eks. hovedmonterede skærme og dens relaterede software og hardware, med organisatoriske rutiner i AIE-organisationer?* Jeg besvarer spørgsmålet ved at anvende teorier om organisatoriske rutiner og "the imbrication lens". Jeg gennemførte fem eksplorerende interviews med virksomheder inden for AIE-branchen. Jeg supplerede disse interviews ved at gennemføre et feltstudie i et arkitektkontor. Under dette 6 måneder lange feltstudie indsamlede jeg observationsdata, omkring 150 dokumenter, design-artefakter og udførte i alt 19 interviews. Min afhandling bidrager til IS-forskning indenfor områderne: fordybende teknologier, teorien om organisatoriske rutiner og til praksis. Jeg bidrager til forskning i fordybende teknologier ved at inddrage de relationelle og opstående egenskaber ved fordybende teknologier. Dernæst viser jeg at hovedmonterede skærmes evne til at lukke brugeren af fra omverdenen kan være en hindring for organisationer, hvis de vil indrullere denne teknologi i deres organisatoriske rutiner. Til teorien om organisatoriske rutine bidrager jeg på følgende måder. Først viser jeg, hvordan teorierne "the imbrication lens" og organisatoriske rutiner kan kombineres for bedre at forstå, hvordan materialiteten i fordybende teknologier ændrer organisatoriske rutiner. For det andet differentierer jeg mellem hvad en teknologi er, og hvad den gør sammen med mennesker, når disse to "imbricerer". Dette giver mig mulighed for at konceptualisere teknologien inklusive dens fleksibilitet og infleksibilitet. Jeg præsenterer således en måde at forstå den rolle, som materialitet spiller, når man undersøger, hvorfor fordybende teknologier undertiden betyder noget; på andre tidspunkter gør endnu mindre for at påvirke organisatoriske rutiner. For det tredje viser jeg, hvordan fordybende teknologier kan skabe variationer på tværs af rutiner og gentager vigtigheden af at bevæge sig ud over organisatoriske rutiner som analyseenhed. For det fjerde lægger jeg grundlaget for en dybere integration mellem organisatoriske rutineteorier og "the imbrication lens". Til sidst bidrager jeg til praksis ved at vise, hvordan og hvornår AIE branchen kan bruge fordybende teknologier til at forbedre samarbejdet med interessenter, hvilket potentielt kan hjælpe med at overkomme nogle aspekter af den lave produktivitet indenfor AIE branchen.

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1 Introduction

Popularized under the name of virtual reality (VR), virtual environments (VEs) have traditionally been associated with sci-fi movies and other entertainment purposes. However, VEs are gradually becoming a phenomenon of great societal impact (Gartner, 2017). From 2010 and onwards, the interest in VEs has been driven by cheaper and more immersive hardware, like head-mounted displays. Immersion is a technology's ability to present a vivid digital space to its user while shutting out the physical reality, like a head-mounted display or a graphically rich VE (Schultze, 2010; Slater and Wilbur, 1997). Immersive technologies increase users' perception of presence in a digital space. Recent studies have shown that immersive technologies' ability to provide users with an increased sense of presence can have a positive effect on productivity, task performance, and collaboration (Colbert et al., 2016; Csikszentmihalyi, 1990; Cummings and Bailenson, 2016).

Despite of these effects, however, the past shows that some instances of immersive technologies have become an essential part of organizations while other instances have remained peripheral. For instance, a type of VE, virtual worlds, were predicted to have a bright future due to their immersive capabilities. However, it remained a peripheral technology that largely failed to catch on outside the realm of entertainment (e.g. Venkatesh and Windeler, 2012; Yoon and George, 2013).

In the architect, engineering, and construction industry (the AEC industry), though, VEs produced using Computer-aided Design (CAD) software have had more success (Baxter, 2008; Boland et al., 2007). Studies conducted have shown that organizations that incorporated more immersive 3D CAD software into their work had a significant influence on their design process and contributed to the development of many new and innovative building designs and work practices (Baxter, 2008; Boland et al., 2007). Contrary to virtual worlds, these studies indicate that when more immersive technologies, like 3D CAD software, are used by organizations in the AEC industry it can have positive outcomes on the collaboration between different stakeholders in construction projects. For example, being able to show richer and more vivid 3D representations, instead of 2D representations, of the different aspects of a construction project contributed to more intense collaboration between the different stakeholders that were involved in a construction project. In particular, because the 3D representation contained more vivid information, it allowed architects, engineers, and other collaborators to: "*…[make] a full visualization of designs in actual scale, and support simulation as well as integration and coordination of detailed design information"* (Boland et al., 2007, p. 636). This in turn contributed to new and innovative work practices because the 3D representations acted, among other things, as more vivid boundary objects between the stakeholders (Boland et al., 2007). With the introduction of head-mounted displays, similar and even more impactful innovations are possible due to, among other things, their ability to facilitate even more immersive VEs. For example, head-mounted displays showing a vivid 3D immersive VE of a building can help identify more errors in the design phase by providing architects and non-professional users with a better sense of scale in the virtual building compared to a 3D immersive VE shown on a traditional monitor.

However, despite these potential benefits that head-mounted displays can have in professional settings, like the AEC industry, they are not widely used in professional settings (Steffen et al., 2019). This is in spite of the beneficial effects that more immersive technologies, like 3D representations, have had on this industry in the past which generally suffers from low productivity. Worldwide, this industry's labor productivity growth has averaged 1 % a year over the past two decades. Compared to other similar sectors, like that of the manufacturing industry, they averaged 3.6 % in productivity growth while the same number for the world economy is 2.8 % (McKinsey, 2017). Being one of the largest consumers of raw materials, many resources in this industry could therefore be saved if their growth in productivity were to catch up with the manufacturing industry or even the world economy, as constructed objects account for 25-40 % of the world's total carbon emissions (World Economic Forum, 2016). An important contributor to the low levels of productivity relates to the fact that the different parts of construction projects are often subcontracted to many specialized firms and trades. During the different phases of any given construction project, from planning and designing to construction, many different organizations with different trades and specialties are involved, like architect firms and engineering consultancies as well as large general contractors. In any given construction project, collaboration between the different contractors and subcontractors is therefore pivotal if for example delays or errors are to be avoided. But issues often arise between stakeholders involved in projects which lead to misunderstandings of contracts and in general to a: *"...hostile contracting environment",* hence contributing to low productivity, due to, among other things, inefficient and mistrusting collaborations (McKinsey, 2017, p. 8). By using immersive technology, like head-mounted displays, that can facilitate more detailed and vivid immersive VEs, these organizations could alleviate some of these issues by providing a better foundation for collaboration through its immersive capabilities – just as the organizations that adopted and used 3D CAD software (Baxter, 2008; Boland et al., 2007). In fact, both industry partners and academics see the use of more technologies such as head-mounted displays as a potential way to increase productivity (McKinsey, 2017; Steffen et al., 2019; World Economic Forum, 2016). For example, if architects and engineers spend 2 % more resources on creating more vivid and immersive 3D models in the early phases of project planning, they could more easily draw on the knowledge of all stakeholders, including the knowledge of layman clients and other relevant professionals, which could potentially save up to 20 % of the total costs of any given project (World Economic Forum, 2016). In line with industry, Steffen et al. suggest that if architects, engineers, or their clients used head-mounted displays: *"…buildings could be seen at true scale as they will appear before construction ever begins, allowing for more accurate models to be communicated"* (Steffen et al., 2019, pp. 699–700), potentially designing buildings of higher quality with the use of fewer resources.

It is therefore relevant to look into immersive technologies, like head-mounted displays, in the context of the AEC industry. Current information systems (IS) research on immersive technologies has come a long way in trying to understand the effects that a specific immersive technology produces on its user. For example, the different types of presence that immersive technologies, like virtual worlds, can provide to their users and to what degree that affects e.g. collaboration. However, current research on immersive technologies has focused mainly on the individual level while black-boxing the immersive technology that facilitates the immersive VEs (Baxter, 2008; Cahalane et al., 2012; Hofma et al., 2018). When focusing on the individual, we ignore the broader organizational context in which the individual is involved. This can be attributed to an overwhelming focus on adoption, use, and continued use as indicated by the frequently used Davis's Technology Acceptance Model (1989). This has led to studies that often use quantitative methods which for example focus on the effects that virtual worlds have on the individual and vice versa. Consequently, current research on immersive technologies has focused mainly on the individual level while black-boxing the immersive technology that facilitates phenomena like virtual worlds, 3D CAD VEs and other immersive VEs (Baxter, 2008; Cahalane et al., 2012; Hofma et al., 2018). These methodological tendencies have also downplayed recent technological developments as the material aspects of the technology have not been conceptualized directly (Cahalane et al., 2012). Whether traditional displays or more advanced head-mounted displays, this black-boxing has led to a simplified view on the role these immersive technologies play in organizations.

With this thesis I thus investigate immersive technology, primarily head-mounted displays, in the context of the AEC industry. I conducted five exploratory interviews with companies primarily within the AEC industry. I later complemented these interviews with an in-depth longitudinal case study in an architect office. The longitudinal case study comprises of 6 months of observational data, 19 interviews, and around 150 documents and design artifacts. With these two studies I more precisely aim to answer the following research question:

How does the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines?

In this thesis I focus on organizational routines to understand the context in which immersive technologies are used. Organizational routines are relevant to consider because they have been regarded as the primary means by which organizations accomplish much of what they do (Feldman and Pentland, 2003). Organizational routines focus more precisely on the repetitive, recognizable patterns of interdependent actions, carried out by multiple actors, and they are an essential aspect of organizations and contemporary work as employees often perform their actions multiple times and together with colleagues (Feldman and Pentland, 2003; Pentland and Feldman, 2005). Therefore, organizational routines also play an important role when trying to understand immersive technologies and the role they play in an organizational context.

I use the theoretical concept of imbrications to zoom in on immersive technologies like head-mounted displays and their materiality, the matter and form, and how they imbricate with organizational routines (Leonardi, 2011). Imbrications focus on the agency of head-mounted displays and organizational routines when they weave together. Leonardi’s framework suggests that if people perceive that a technology affords them the possibility to achieve new goals, it leads them to change their organizational routines, and if people perceive a technology as a constraint, with regard to achieving specific goals, people change their technologies instead. By illustrating imbrications of human and material agency, I offer a detailed analysis of the use of primarily head-mounted displays in the AEC industry and show how the recursive interweaving of technology and humans can potentially change organizational routines or technologies.

I complement organizational routines theory with Leonardi’s concept of imbrications because the concepts of organizational routines theory do not explicitly conceptualize the matter and form of technology. In particular, humans and technology are often referred to through the concept of actants by organizational routine scholars. By doing this they cast these two entities, humans and technologies as hybrids. Thus, who or what does what is not the main focus of attention. Instead, focus is on the actions of humans and nonhumans, actants, which deliberately do not distinguish if it is a human or a nonhuman that is doing any given action (Leonardi, 2012, 2011; Pickering, 1995). While these concepts are important to portray a more nuanced picture of the relationship between technologies and organizational routines, these concepts tend to overshadow the matter and form of technologies. In particular, the concept of actants shift focus away from the materiality of technology to the agency of humans and nonhumans. In other words, when organizational routines scholars employ the concept of actants, they therefore risk shifting attention away from the materiality of technology by focusing on what humans and technologies do together as actants (Leonardi, 2012, 2011; Volkoff et al., 2007).

I have thus chosen to view the immersive technologies through the lens of imbrications because one of the main objectives of this thesis is to shed light on immersive technologies and its matter and form to better understand how immersive technologies, primarily head-mounted displays imbricates with organizational routines.

In the following I will elaborate on how these dispositions and the thesis in general contributes to research and practice.

1.1 Research contributions

This study contributes to IS research on immersive technologies, the theory of organizational routines, and lastly to practice.

To research on immersive technologies, I aim to contribute with the following ways. First, using the imbrication lens, I contribute to research on immersive technologies by attending to the relational and emergent characteristics of immersion - an aspect that has been undertheorized in current research on immersive technologies (Cahalane et al., 2012; Schultze and Orlikowski, 2010). In particular, current theories use of immersion in IS research, takes a stance which presumes: *"…the existence of independent objects with fixed or given* [material] *properties and boundaries…"* (Schultze and Orlikowski, 2010, p. 814). In contrast, I argue that immersiveness of head-mounted displays, and other immersive technologies, depends on how it intertwines and imbricates with the human agencies and other technologies. This way, I extend the theory on immersive technologies by focusing on the relational and emergent characteristics of immersion to shed light on this undertheorized aspect in research on immersive technologies (Cahalane et al., 2012; Schultze and Orlikowski, 2010).

Second, I also seek to contribute to a specific stream of literature within immersive technologies research which look into the adoption of immersive technologies. In particular, in a recent study on the adoption of head-mounted displays Steffen (2019) hypothesized that head-mounted displays ability to shut users off from their surrounding environment is a significant modifier for users to experience the affordances of VR and thus for organizations to adopt VR in the first place. However, Steffen et al. (2019) study conclusion is ambiguous suggesting for future research is needed to better understand the role that the materiality of head-mounted display has for the adoption of this immersive technology. By employing the imbrication lens I show that head-mounted displays inclusiveness, it ability to shut users off from the surrounding environment, can be an obstacle for organizations when enrolling and retaining head-mounted displays in their organizational routines (Steffen et al., 2019).

To literature on organizational routines theory I aim at contributing in the following four ways. First, by keeping what technology is separate from what it does together with humans, the form and matter of technologies can be directly conceptualized. This thesis shows, as many scholars have already pointed out, that materiality is important to include and theorize as a distinct phenomenon in order to understand how not only immersive technologies, but also IT in general change organizational routines. With my thesis I build on this by illustrating how the imbrication lens and organizational routines theory can be combined to better understand how the materiality of immersive technologies changes organizational routines, as suggested by IS and organizational routines scholars alike (Feldman et al., 2016; Leonardi, 2012; Pentland et al., 2012; Robey et al., 2013).

Second, with this thesis, I contribute to organizational routines studies by introducing the imbrication lens into organizational routines studies. And by doing so means that the technology's materiality and how it determines the flexibility and inflexibility are directly conceptualized by keeping what technology is separate from what it does together with humans, when it imbricates. Different directions within organizational routines theory have provided many insights into this area. However, as the review of literature on organizational routines shows they predominantly use theories and concepts, like Actor-Network theory, that insist that organizational routines and artifacts are indistinguishable phenomena. By identifying this gap in organizational routines literature and using the imbrication lens to alleviate these shortcomings, I aim at contributing to organizational routines theory. In short, by introducing the imbrication lens to organizational routines theory, I contribute to this research stream by providing a way to better understand the role that materiality plays when trying to understand why immersive technologies sometimes *"...matter a great deal; at other times, they only minimally encode a routine and do even less to influence its ongoing use."* (Parmigiani and Howard-Grenville, 2011, p. 445).

Third, I show how immersive technologies can create variations across organizational routines, in turn contributing to organizational routines research. In particular, I demonstrate how an immersive technology, such as head-mounted displays and software plug-ins, interacts to create variations not only within but also across organizational routines. I thus reiterate the importance of moving: *"...beyond organizational routines as the unit of analysis and consider relations among routines and networks of routines"* to better grasp how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines (Feldman et al., 2016, p. 511).

Lastly, I contribute to organizational routine research by laying the foundation for a deeper theoretical integration of the two theories, organizational routines and the imbrication lens, which is an important step to understand technology's role in organizational routines research, as hinted by scholars concerned with organizational routines theory (Feldman, 2016; Pentland et al., 2012). To the author's knowledge, however, this has not yet happened within organizational routines research. With this thesis, I take a first step to integrate the imbrication lens with organizational routines theory more in-depth, which is necessary in order to understand how and what aspects of organizational routines can potentially change when human and material agency imbricate.

I aim at contributing to practice in the following way. While head-mounted displays and other immersive technologies have not been adopted at the rate initially expected, the market for these technologies is continually growing and could potentially change the way organizations interact and collaborate (Gartner, 2017; Steffen et al., 2019). It is therefore important to highlight the potential implications for organizations when they enroll and retain these technologies in their organizational routines to better understand why these immersive technologies sometimes matter in organizational routines but at other times do not. Hence, with this thesis I show how and when companies in the AEC industry can use immersive technologies to improve collaboration with stakeholders, professionals and laymen alike, during the design phase of building projects, potentially alleviating some of the productivity issues of the industry. These findings could in turn help organizations from other industries as well to identify strategies that could help them to exploit the benefits that immersive technologies, like head-mounted displays, might offer in the future.

1.2 Overview of theories and definitions

To summarize, with this thesis I will investigate how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. To better understand how I will investigate my research question, in the following I will present a brief summary of the theories and concepts I use in my thesis (see Figure 1).

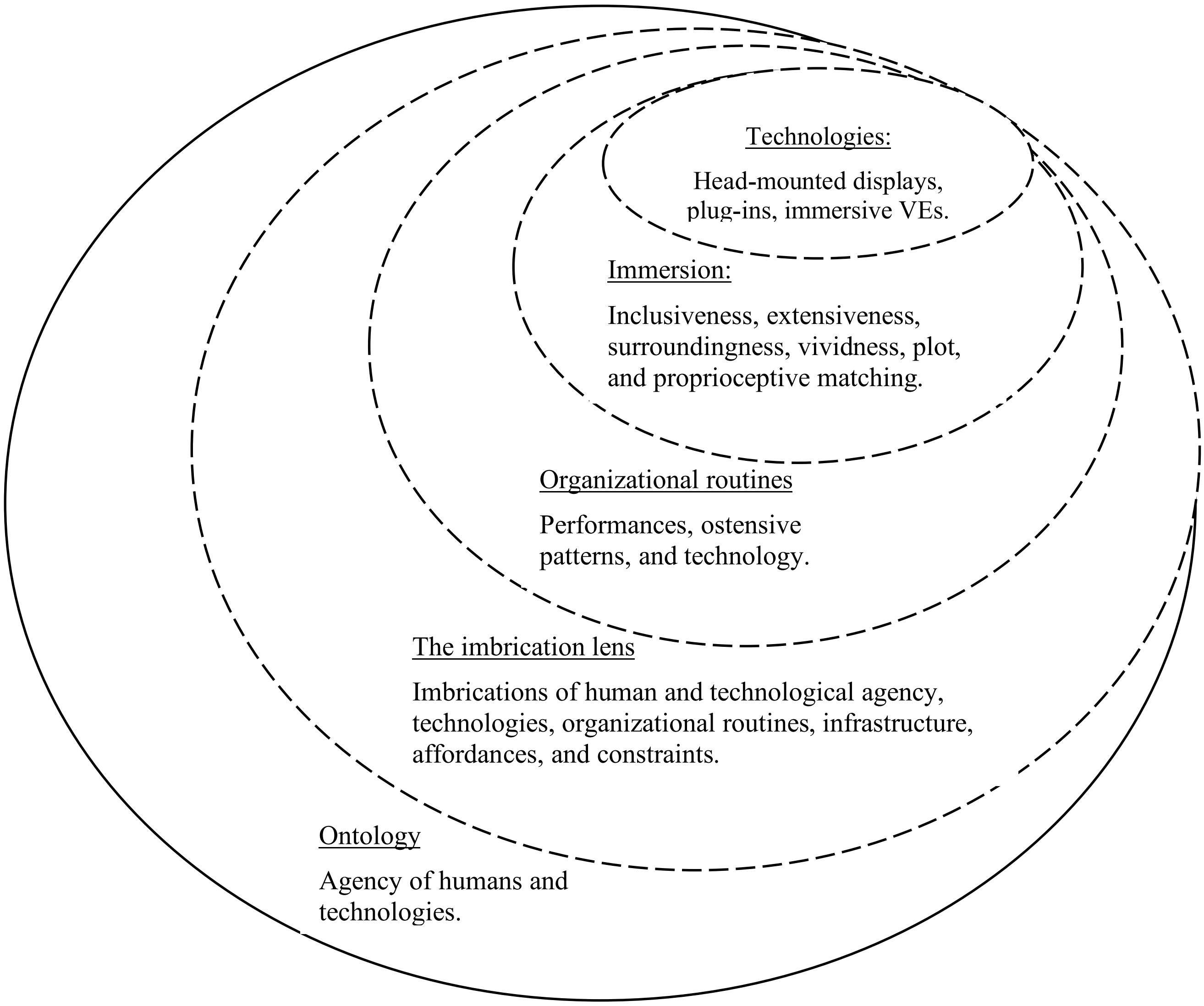

Figure 1: Overview of theories, concepts, and their relations.

Head-mounted displays are characterized as an immersive technology that can produce immersive VEs. In my data these immersive VEs are primarily produced by plug-ins to existing software. Head-mounted displays and immersive VEs are immersive because they can shut users off from the surrounding environment physically and mentally (inclusive), they accommodate a range of senses like the visual and auditory senses (extensive), they provide users with a panoramic instead of a more narrow field of view (surroundingness), they have the ability to display vivid and lifelike immersive VEs to users (vividness), and lastly, users can interact with the VE (plot) in a natural manner, e.g. by looking around using their head (proprioceptive matching) (Slater and Wilbur, 1997).

To better understand how the matter and form of head-mounted displays, and other immersive technologies like immersive VEs, influence and interact with the everyday work of employees in AEC organizations, I utilize organizational routines theory and the imbrication lens. Organizational routines' (Feldman and Pentland, 2003) main unit of observation is on the performances (agency) of humans and technologies, while the unit of analysis is the repeated and interdependent patterns of the two – that is the ostensive pattern of the organizational routine (Feldman et al., 2016). I utilize the imbrication lens (Leonardi, 2011) to zoom in on how head-mounted displays and their materiality influence human actors, their performances, and ostensive patterns.

To encompass these theories and bridge the methodological gaps in literature on immersive technologies I build on a relational ontology that views the world as consisting of human and material agency (Leonardi, 2012, 2011). Thus, immersive technologies, organizational routines, and imbrications of humans and technology are relational phenomena. Consequently, with theses theoretical perspectives I see their properties as emergent and dependent on each other and in which the context they exist.

1.3 Outline of the thesis

This thesis is structured in nine chapters as described below.

Chapter 1 – Introduction

In the introduction I initially outline the existing research on immersive technologies and how these technologies, in particular head-mounted displays, are not being adopted and used to the extent that many expected – despite the benefits that previous immersive technologies have shown in the context of the AEC industry. I therefore pose the following research question: *How does the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines?* I then go on to present the contributions, the terms and definitions, and lastly the outline of this thesis.

Chapter 2 – Philosophy of science

In this chapter I lay out a performative philosophy of science with which I am to better understand how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. Initially, I present the ontology – what the field is constituted of. Next, I explain how I define, in more detail, human and material agency. This is followed by a section that explains the difference between human and material agency. Lastly, I provide a description of the epistemological implications of the employed ontology.

Chapter 3 – Literature review: immersive technologies in IS literature

In this chapter I review the artifacts and the research approach of 120 articles on the topic of immersive technologies in IS. I start out by initially describing the design of the review. Then I present the theoretical background of immersive technologies. The review of the articles itself then starts with a section describing and analyzing what aspects of immersive technologies the articles have focused on. Lastly, I present a section on the research approaches identified in the review. I conclude that IS researchers have the typically studied software immersion, with a majority of articles focusing on the individual, while frequently using Davis's Technology Acceptance Model (1989) which is measured quantitatively through survey data.

Chapter 4 – Theoretical background: organizational routines and the imbrication lens

In this chapter I present the theoretical background of this thesis: organizational routines theory and the imbrication lens. First, I describe how organizational routines theory perceives technology. With this I aim to provide a way to theorize and map out how primarily head-mounted displays are enrolled or not enrolled into organizational routines, by focusing on the performances and repetitive patterns of actors and technologies in organizational routines. I conclude this chapter by introducing the imbrication lens with which I aim to extend and complement organizational routines theory's view on technologies. Specifically, the imbrication lens focuses in more detail than organizational routines on the changes that head-mounted displays have on organizational routines and vice versa, while preserving a focus on materiality.

Chapter 5 – Method: data collection and analysis

In this chapter I present a description of the data collection and the subsequent data analysis. Both the collection and the analysis of the data consists of two phases, first the explorative phase and subsequently the longitudinal phase. In the section on data collection, I initially describe the data collection for each of the two phases including a presentation of the empirical settings. Next, I describe the style of involvement during the collection of the observational data and lastly, I describe how I have gathered the three types of data, interviews, observations, and artifacts in the second phase of data collection. In the section on data analysis, I initially describe how the interviews were transcribed. Then I present how the data was analyzed, first in a general manner and next describing the specific methods for each of the two phases.

Chapter 6 – The first explorative phase: analysis and findings

This first explorative analysis presents data from five organizations. For each of the five organizations, an organizational meeting routine was initially identified. After that the use of head-mounted displays, and its related hardware and software, was analyzed together with their interactions with the organizational routines, through the use of thematic analysis and meaning condensation as a method.

Chapter 7 – The second longitudinal phase: analysis and findings

This chapter describes the two organizational routines and the use of primarily head-mounted displays in each of them – an internal and an external organizational routine. The internal organizational routine is a design routine while the external organizational routine is a meeting routine. The data from the longitudinal analysis was analyzed using the imbrication lens and organizational routines theory.

Chapter 8 – Discussion: findings, contributions, and limitations

In this chapter I present and synthesize the findings of the two studies, the explorative and longitudinal study. In the following section I build on these findings and show how they contribute to research. Lastly, I discuss the merits of the imbrication lens in relation to the socio-technical and (other) sociomaterial approaches

Chapter 9 – Conclusion and future research

In the concluding chapter of this thesis I will initially summarize the findings of my study. I end this chapter and my thesis by suggesting research directions that could be further explored by IS researchers on immersive technologies and organizational routines scholars in future studies.

2 Philosophy of science

In this chapter I lay out my view on a relational philosophy of science with which I aim to better understand how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. Initially, I present the ontology – what I see the field is constituted of. Next, I explain how I define, in more detail, human and material agency. This is followed by a section that explains the difference between human and material agency. Lastly, I describe the epistemological implications of the employed ontology with the intent of defining what type of knowledge I am trying to generate from this thesis.

2.1 The ontological view: humans, technology and agency

The units of observation of this thesis are primarily head-mounted display, organizational routines, and the imbrications of human and material agency. To conceptualize these phenomena, I will primarily draw on Leonardi's definition of technology[1], humans and their agency (Leonardi, 2012, 2011). While I do mention some of Pickering's definitions of agency as Leonardi, in part, build on his idea of material agency, the relational ontology that I use in my thesis predominantly stems from Leonardi (Leonardi, 2012, 2011).

Both the imbrication lens, but also organizational routines theory, see humans and technology as separate entities. However, they also stress that humans and technology have agency. Thus, in my thesis the focal point of analysis will be on the agency of both humans and technology. That is, focus is on what humans and technology do together as I see the world as continually doing things (Leonardi, 2011).

As the world is filled with agency, I further argue that humans and technology both have the capability to act. Intuitively, it is easy to imagine that humans have the capability to act. However, when technology, like head-mounted displays, capture forces in the world, those forces gain material agency and thus the capability to perform actions on their own, apart from human intervention (Leonardi, 2011; Pickering, 1995). Forces in this sense simply refer to anything

[1] Research traditions, like Science and Technology Studies, use the concept nonhumans to encompass everything that is not human, e.g. scientific equipment (Pickering, 1995) or even: "*...microbes, scallops, rocks, and ships"* (Latour, 2005, p. 10). … In my thesis I will therefore primarily use the word technology instead of nonhumans going forward. If the concept nonhuman is used it refers to digital technology.

outside the human realm. And these material forces drive phenomena like the weather: winds, heat, floods. And as humans we constantly need to respond to and cope with this material agency in much of everyday life. These forces therefore play a significant role for humans and their agency and should not be reduced to or conflated with anything within the human realm (Leonardi, 2011). Rather, these forces are captured in technology, like head-mounted displays, and provide technology with the ability to perform actions without the need for human intervention. Human agents and their doings therefore exist in a field of doings which humans struggle to capture in machines and technology. For example, the current versions of head-mounted displays are a result of long and many efforts done by engineers and scientists who have struggled to capture electrons in a way that makes it possible to process them quickly enough so that they can create a vivid VE which in turn can make its users feel immersed in a VE.

The actions of the field I investigate can thus be captured in technology in turn providing them with agency. I therefore argue that technology has material agency which is important in order to understand when immersive technologies are enrolled or not enrolled into organizational routines.

This continual and mutual adaptation between humans and technology is analogous to that of tuning a radio, with the critical detail, though, that what type of radio station you catch is not known or determined in advance (Pickering, 1995). Importantly, the tuning goes both ways. The architect using the head-mounted display does not know beforehand when or, for that matter, where to use the display. How the head-mounted display acts has to be discovered in the moment of use. Pickering describes this moment in time in the following way: *"…human and material agencies are reciprocally and emergently intertwined* [weaved together] *in this struggle…*[the human and material] *contours emerge in the temporality of practice and are definitional of and sustain one another."* (Pickering, 1995, p. 21).

Hence, I argue that actions are always situated in space and at a particular time and these aspects are important to take into account in order to understand the agency of humans (e.g. actors in an organizational routine) and technologies (e.g. head-mounted displays). For example, a head-mounted display might be highly immersive at one point in time in a specific office space where the user does not have to interact with her colleagues, and be less immersive at another point in time where the user most likely needs to socialize with others in the same office space (or in another office space).

The epistemological implications of this ontology are that this thesis seeks to produce accounts that focus on the actions of humans (e.g. architects) and technologies (e.g. head-mounted displays), and hence both are seen as having the ability to act. As humans and technologies interweave they define and constitute each other's capabilities and attributes – they emerge and are therefore in line with a relational view on ontology (Leonardi, 2011). Because human and material agency is constantly happening, my analysis focusses on specific moments in time where humans and technologies act together in temporarily. By applying this form of ontology and epistemology to my thesis, the technology is given agency which, in turn, I can use to better understand the relations that emerge when head-mounted displays, and its related hardware and software, imbricate with organizational routines and vice versa.

Key concept(s)	**Definition(s) and explanation(s)**
Human agency	The capacity to perform actions and to form and realize one's goals.
Material agency	The capacity to perform actions, apart from human intervention.

Table 1: Key concept(s) used in this section.[2]

2.1.1 The differences between human and material agency

However, while the ontological stance is that both human and technology have agency, it is important to stress that their agency do differ as human agents have the ability to form intentions on their own but technological agents do not. By intentions I simply refer to how human agents typically organize around specific plans and goals. I therefore define human agency as the ability to form and realize one's goals (Leonardi, 2012, 2011). This does not imply that technologies do not have intentions. Instead, while technologies can have intentions inscribed into them, at "the end of the day" they are often formed by humans.

With this definition, some important matters need to be clarified. First, the focus of this thesis is still on human and material agency – that is, their actions, and not the intentions of humans alone. These intentions are "simply" stated and followed but not intended to be used as an explanation in themselves. This is done to avoid that the actions of technology are explained by a humans' actions and their intentions exclusively. Instead, focus is on both humans' and technology's

[2] For each section I will summarize the most important concept(s) in a table by providing a definition and/or explanation for each one.

actions when they weave together and on how they mutually shape and reshape each other to emphasize that material agency plays an important role.

But what is the role, more specifically, of a technology as it performs actions and tunes in on the agency of a human? To understand the actions of technology during this moment, I draw on Leonardi's argumentation and the fact that it is important to differentiate between what a technology is and how a technology acts (Leonardi, 2012, 2011).

The motivation for using Leonardi (2012) is that he has since used, extended, and elaborated Pickering's definition of the same concepts into the realm of digital technologies, which is the primary focus of this thesis. And more importantly, as mentioned, by making a distinction between what a technology is and how a technology performs, Leonardi (2012) highlights that both of these aspects of technology play an important role in the constant tuning with human agency.

To make the implications of this distinction clearer, thereby explicating the ontology of my thesis, the following sections will first elaborate on the definition of materiality and its implications and how materiality is different from the actions of technologies.

Key concept	**Definition and explanation**
Intentionality	The ability to form and realize one's goals

Table 2: Key concept(s) used in this section.

2.1.2 The materiality of technology: matter and form

To conceptualize the technological phenomenon of this thesis, head-mounted displays and its related hardware and software, I draw on Leonardi (2012) and his view on materiality. Materiality refers to a technology's physical and/or digital materials which can be arranged into specific forms. In my thesis I pay particular attention to head-mounted displays, and the materials or matter refers to the physical casing and/or the VE that it produces. The form points to the shape of a technology, for instance the rectangular form of a head-mounted display. Lastly, the matter and form also help to conceptualize those aspects of technology that can potentially be stable across contexts and are important to users. In short, materiality is: *"The arrangement of an artifact's physical and/or digital materials into particular forms that endure across differences in place and time and are important to users"* (Leonardi, 2012, p. 14).

This definition helps to put focus on the materiality of the main technological phenomenon of this thesis, head-mounted displays, as it makes a distinction between what a technology is, its materiality, and the agency of technologies, which helps in the following three ways. First, the materiality plays a vital role for head-mounted displays' immersive capabilities, an important aspect of this thesis, as the matter and form shut users off from the surrounding environment. Second, separating what a technology is (materiality) with what it does (its agency) also emphasizes that when humans and technologies tune in on each other, it is important to account for the materiality of the head-mounted displays, and for other technologies that are part of interweaving, as materiality have a significant influence on how humans and technologies define and sustain each other during their actions. For example, whether or not the head-mounted display shuts a client off from the surrounding environment when he or she is walking around in an immersive VE, materiality still plays a role in the interweaving of the client and the head-mounted display. Third, and lastly, the definition of materiality also helps to underline that there are some aspects of technologies, the matter and form, that are different from humans and their agency. In particular, the matter and form of head-mounted displays are potentially more durable across place and time and they cannot form their own intentions – unlike humans.

In the following I will elaborate on the definition of materiality and show how it can help to explain the above-mentioned points and thus help to show how head-mounted displays, and related hardware and software, can condition human actions and vice versa when they weave together and define and sustain one another.

As the definition implies, materiality consists of matter and form. The matter points more precisely to e.g. the plastic of the casing and the glass of the lenses of head-mounted displays. However, while it is relatively easy to identify the physical matter, it is harder to do the same with the digital equivalent which have no physicality. To exemplify the difficulty in identifying what material the digital is made of, one can for example ask: what material is a digitally modelled house constituted of? Is it the programming language of the CAD software? This difficulty first of all underlines the importance of conceptualizing matter directly. If matter is only addressed indirectly or conflated with the actions of technologies, it can be hard to distinguish and explain how exactly the matter influence the interweaving of human and technological agency. This can result any given observer in overlooking the material, both the digital and physical matter, and the influence it has on the interweaving of humans and technologies – as much literature within IS research has argued before (e.g. Cecez-Kecmanovic et al., 2014; Orlikowski, 2000; Orlikowski and Barley, 2001).[3]

But matter is not the only thing that identifies technologies. Form is equally important and can encompass the digital aspects of IT artifacts (Leonardi, 2012). For example, the aforementioned materials of the head-mounted displays have a particular form, e.g. the plastic is formed as a casing, the glass as lenses. But the digital materials also have a form, e.g. the particular form of the menus or the avatars in any given VE. Material*ity* thus encompasses both matter and form. Together, matter and form help to shed light on both the digital and the physical aspects of the primary object of study of this thesis – the head-mounted displays as well as the immersive VEs that they produce.

Notable scholars have pointed out that technologies are: *"...never fully stabilized or complete even though we may choose to treat them as fixed, black-boxes for a period of time"* (Orlikowski, 2000). Much of especially digital or virtual software is frequently changed and updated. For example, popular software programs like Excel or Word 2010 evolve over time which makes its materiality quite different from today's versions of these programs. However, importantly, these and much of their material aspects remained quite constant for a significant period of time and are important to consider *as well* as the changes to it. In the words of Leonardi: *"Saying that a technology has a materiality is to say that its materiality has indeed stabilized...for now. And it is this stabilization that allows two people working on the same document, drawing, or database to share work with each other."* (Leonardi, 2012, p. 5).

However, with this definition of materiality used in this thesis, focus will be limited to the parts of materiality that: *"...are important to users"* as many other aspects of digital artifacts have the potential, at least, to change. For example, the form of the underlying code as it is executed when users are putting on a head-mounted display and walking around. But it will not necessarily have an influence on the specific instances of "tuning" of human and material agency that are under investigation. Thus, when referring to a technology's materiality, it is about the parts that are important to the interweaving of human and technological agency.

Thus, with this definition of materiality I recognize that the materiality of technologies is different from their material agency. That is, what a technology is*,* is different from what it does. This is

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[3] See the discussion chapter for a further elaboration on socio-materiality and its role in this thesis.

important in the following ways. First, it focuses attention towards the immersive capabilities of head-mounted displays – an important feature for this thesis and head-mounted displays in general. Second, it directs attention to the fact that no matter if a user is immersed in a VE or not, the matter and form of head-mounted displays, and other involved technologies, play an important role when they weave together with human agency. Third and lastly, the matter and form (materiality) help to conceptualize technology directly as it is distinct from humans and their agency: technology and its materiality is potentially more durable, across time and place, but do not have the ability to form its own attentions. In short, by conceptualizing the materiality of technology through matter and form one can better identify the role that materiality has when its technological agency weave together with the human equivalents.

Key concept(s)	**Definition(s) and explanation(s)**
Materiality	The arrangement of a technology's physical and/or digital materials into particular forms that endure across differences in place and time and are important to users.
Matter	The material that a technology, physical and digital (if identifiable), is made of.
Form	The form of a physical and/or digital technology, e.g. the form of the button in a CAD program.

Table 3: Key concept(s) used in this section.

2.2 Summary of the ontology and its epistemological implications

The main focus of this thesis is on the interaction between the human and the technological agency and as the two tune in on each other, they play an equally important role in shaping each other's agency. To reiterate, human agency is the ability to form and realize one's goals and material agency is the doings that are captured in machines. More precisely, Leonardi's definition of material agency is: *"…the capacity for nonhuman entities to act absent of sustained human intervention"* (Leonardi, 2012, p. 9). However, in contrast to humans, technologies do not have the ability to form their own intentions. And at the end of the day, it is always humans that decide: *"…how it* [technology] *will become interwoven with their goals"* (Leonardi, 2011, p. 150). For example, the underlying code of a CAD program does execute absent of human intervention, but it does not have an intention to do so. That is not to say that the technology is neutral, as it can be inscribed with intentions and transform them in different ways. But the intentions are initially formed by humans and their agency.

Further, Leonardi's distinction between the technology itself and its material agency has the following implications for my thesis. First, it focuses attention towards the matter and form of head-mounted displays and their materiality's to shut users off from the surrounding environment and potentially immerse its users. Second, what materiality (matter and form) helps to point out is that what a technology *is* (the materiality) can change but often does not change across time and place. But what the technology *does*, its agency, can and often does change. To exemplify: the matter and the form of a head-mounted display itself (materiality) that is under investigation, e.g. the plastic casing and the glass lenses, will not change across time and space in any significant way for the users. For instance, no matter the time or place, the plastic casing will physically shut users off from the surrounding environment and therefore shape the interactions with its users in an important way. Hence, materiality plays a role in the interaction with humans, no matter the outcome – e.g. if the user is immersed in the VE or not. Third, and lastly, conceptualizing the matter and form as distinct from humans, the agency of humans, and the agency of technologies, the head-mounted display's ability to potentially immerse users across place and time, its durability, is not overshadowed by e.g. human or technological agency when human and technologies interact and weave together. For example, in most cases, the materiality of the head-mounted display is durable across contexts and will shut users' visual sense off from the surrounding environment. Just as significant parts of the virtual environment software, its underlying code etc., remain the same in order for it to remain compatible with the head-mounted display. Thus, some aspects of immersive technologies cannot be changed as these stable parts are what provide them with its potential ability to immerse its users. However, what users do with the head-mounted display or the virtual environment software is a different matter.

Together, these ontological premises have implications for the epistemological view of my thesis. In particular, I see the world as consisting of doings or agency, hence the ontological foundation for the theories that I introduce in the subsequent chapters, namely organizational routines and the imbrication lens. Thus, the primary unit of observation is on the agency of humans and technologies and how they unfold when they weave together. The epistemological implication of this view is that I do not seek to produce predictions in a conventional or statistical sense, for example by creating theoretical concepts that account for and explain *why* all current and future head-mounted displays are e.g. not used or are used. Instead I seek to produce theoretical generalizations which travel across contexts, by explaining *how* situated dynamics and relations guide actions in other contexts, and which offer insights for understanding: *"...other situations* *while being historically and contextually grounded"* (Orlikowski and Feldman, 2011, p. 1249). For example, by producing a theoretical framework or concept that provides a guide to other and similar contexts and will be able to show in what situations that head-mounted displays can potentially immerse their users. In turn, this can potentially guide actions in other contexts.

In the following sections, I elaborate further on through what lenses (theory) and how (methods) and I seek to accomplish this kind of knowledge with which I am to answer my research question: *How does the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines?*

However, before elaborating on the methods and theories, I will review literature on immersive technologies in IS literature, with the aim of elaborating on the status of immersive technologies in IS literature – the primary focus of this thesis.

3 Literature review: immersive technologies in IS literature[4]

In the following chapter I review research on immersive technologies. The motivation for doing a literature review stems from Cahalane and colleagues' (2012) review on virtual worlds, a specific instance of immersive technologies in which they argue that research seems fragmented with many different interpretations of important concepts such as immersion, while also reasoning that research on immersive technologies has understated the material aspects of immersive technologies – that is the actual material and form of the hardware (Leonardi, 2012).

Given this thesis focus on immersive technologies, including the hardware that facilitates immersive VEs as well as the rapid development of the underlying technology, I present a literature review on immersive technologies in the following section. In particular, I review the technologies, and the research approach taken to investigate the immersive technologies in IS research. What technology is chosen to represent a problem domain, and how it is studied, both have important impact on the conclusions and the theory development that can be made (Venkatesh et al., 2013). With this review, I first of all aim to better understand how to position my thesis in IS literature. Second, by reviewing how previous literature has conceptualized immersive technologies like head-mounted displays, I aim to better understand why immersive

[4] Based on: Hofma, C.C., Henningsson, S., Vaidyanathan, N., 2018. Immersive Virtual Environments in Information Systems Research: A Review of Objects and Approaches, in: AOM Proceedings. AOM Briarcliff Manor, NY 10510, p. 13932

technologies are sometimes enrolled and retained in organizational routines but at other times are not.

Before going into the actual review, I will initially describe the design of the review. Then I present the theoretical background of immersive technologies. The review of the articles itself then starts with a section describing and analyzing what aspects of immersive technologies the articles have focused on. Lastly, I present a section on the research approaches identified in the review. The section will encompass a review of: the types of data gathered, how the data was analyzed, the theories applied, and lastly the level of analysis chosen by each article reviewed.

3.1 The literature review process

This thesis reviews the literature related to the topic of immersive technologies. The literature that I selected for review was chosen to unfold how immersive technologies, such as head-mounted displays and virtual worlds, have been investigated in prior literature. Just like previous literature reviews within IS on immersive technologies (Cahalane et al., 2012; Schultze, 2010), this literature review limits itself to IS research. Literature on immersive technologies exists in related research disciplines such as engineering, computer sciences, and psychology. Furthermore, concepts such as presence and immersion spring from the disciplines of engineering and psychology, respectively (Cahalane et al., 2012). However, within these research disciplines, focus is mostly on the objects themselves, the immersive VEs or head-mounted displays (engineering and computer sciences), or on the response they produce on individuals, e.g. the degree of presence a user feels when in an immersive VE (Fox et al., 2009). In this thesis, however, focus is not only on the technical aspects or psychological effects on the individual but, as stated in the research question, on how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

Thus I have limited the scope of the review to highly ranked IS journals as well conferences within the IS discipline as suggested by Webster and Watson (2002). That is, the Basket of Eight and the highest ranked conferences of AIS: ICIS, AMCIS, PACIS, and ECIS (Vom Brocke et al., 2009; Webster and Watson, 2002). The review also included the management journal Organizational Science which also publishes IS research.

The scope is further narrowed down by focusing on peer-reviewed material only, thus excluding material such as research in progress papers, books, and popular articles. The articles were found by searching SCOPUS, Google Scholar, and the AIS library using the following key words and search operators:

> "augmented realit*" OR "mixed realit*" OR "virtual realit*" OR "virtual environment*" OR "immersive virtual environment*" OR "virtual world*" OR 3D OR 3-D OR CAD OR "computer-aided design*"[5]

The search of keywords was restricted to the title and/or abstract, which resulted in 183 articles. Next, articles published before 2007 were excluded resulting in 153 articles. 2007 was chosen as the cut-off point because this was the year when IS scholars started to publish articles on a specific type of immersive technologies, virtual worlds, after the initial media "hype" in 2006 (Cahalane et al., 2012; Wasko et al., 2011). 32 articles were furthermore removed as they had limited relevance to the topic, e.g. papers on 3D printing or papers that briefly mention 3D.

At the end I chose 120 articles for further review. Of those the vast majority, 119 of the 120 articles, focus on either virtual reality, virtual environments, virtual worlds, or CAD software while only one article focuses on augmented reality. Thus, the review will heavily favor a specific instantiation of immersive technologies: virtual worlds. From 2007 to 2017, the total number of articles published in the AIS outlets peaked with 28 articles in 2009 (see Figure 2). This peak correlates with the hype of virtual worlds which were driven by Second Life – an immersive technology used primarily for entertainment purposes. From 2008 to 2010, 51 out of 59 articles were published in conference proceedings. In 2011 and 2012, 30 out of 69 articles were from special issues on virtual worlds in MISQ and JAIS, thus increasing the percentage of journal publications indicating a heightened interest in immersive technologies at that particular time.

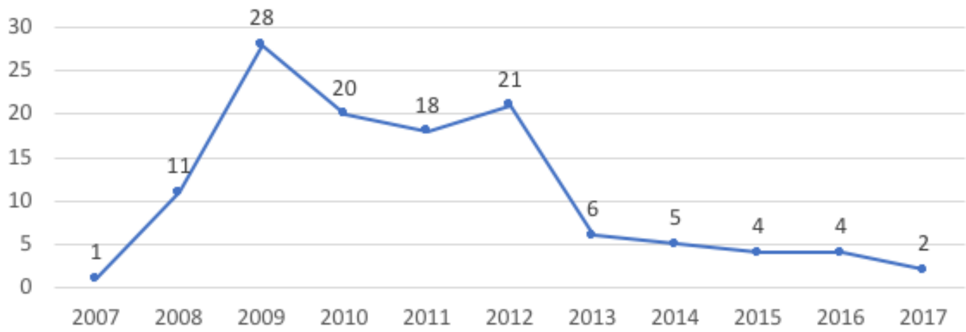


Figure 2: Articles published by year

[5] Augmented reality was included in the keyword search, despite not being the object of focus of this thesis, as this technology is often mentioned together in especially popular or industry literature (Gartner, 2017, 2013)0/0/00 0:00:00 AM.

However, from 2012 onwards, there is a sudden drop in articles published. Articles published after 2012 were almost evenly distributed between conference proceedings and journals. The rise and drop in publications fit with the predictions made in Gartner's Hype Cycle. In 2007 they had placed "virtual worlds/virtual environments" at the peak of inflated expectations, predicting it to reach the plateau of productivity within five to ten years (Gartner, 2007), but in 2013, virtual worlds were completely removed from the hype cycle. In the following years, however, virtual reality was added to the hype cycle, and in 2017, it was expected to reach the "Plateau of Productivity" (Gartner, 2017, 2013). This shows that this type of immersive technologies is not a new phenomenon as different instances of this technology have caught the interest of both industry and research to varying degrees over the last 10 to 15 years – at least (e.g. Fox et al., 2009).

With this thesis and review, however, I choose to focus on the period from 2007 to 2017 where the current interest in immersive technologies seems to have started, reflected in both the increasing number of academic articles and in the Gartner Hype Cycles.

3.1.1 Coding

The literature was copied into an Excel sheet to create a concept matrix which is an approach that was inspired by Webster and Watson's article on how to perform a literature review (Webster and Watson, 2002). The coding was done by the author over several iterations. During the first iteration, I identified the research approaches of each article which includes: how the data was analyzed, the theories applied, and lastly the level of analysis chosen by each article reviewed. The data analysis and data type refer to how the data was analyzed and how it was done, while the theoretical aspect relates to what kind of theories are employed on the data. Where possible, these dimensions were identified from the abstract, but for the majority of the articles, the dimensions were identified from reading the introduction and the methods section.

After the first iteration, I identified dimensions in each of the articles which related to what had been investigated, and which were subsequently coded, if relevant. These dimensions are: the technology and the context. The technology dimension refers to the type of technology investigated and the context to the empirical setting, e.g. industry in which any of the research were conducted.

Research approach: How has it been studied in the literature?	
Data Analysis and Data Type	Quantitative, Qualitative, and Mixed Methods
Theoretical Perspectives	Theories applied e.g. Technology Acceptance Model (Davis, 1989)
Level of Analysis	Individual, Relational, Groups, Organizational, Inter-Organizational, and Society
Object of study: What has been studied in the literature?	
Technology	Software Immersion Only, Mentions Hardware Setup, Software and Hardware Immersion, Hardware Immersion Only
Context	Education, Virtual Worlds, N/A, Retail and Marketing, Unspecified Business Setting, Recreational, Health Care, AEC Industry, Software Industry, Human Resources, Product Development

Table 4: Coding dimensions and values.

Before going into the review, however, I will briefly present the theoretical background of immersive technologies.

3.2 Theoretical background of immersive technologies

An immersive VE is a digital space. In an immersive VE, a user's movements are tracked either by a keyboard or by sensors in an immersive technology such as a head-mounted display. And while the user moves around in the digital space, his or her surroundings are digitally composed and displayed to the senses, in accordance with those movements (Fox et al., 2009, p. 95). In this case, the digital space is typically showing a building, e.g. a house, while his or her surroundings can be tracked by sensors built into the head-mounted display. Traditionally, immersive VEs have been displayed on a screen while the movements of the user have been tracked by a keyboard or a mouse. The goal of an immersive technology is to cover or substitute the input from the surrounding real world with digital input (Fox et al., 2009). The more successful an immersive technology is in replacing cues from the physical world with digital ones, the more the chance of immersing the user increases. Immersion refers to a technology's capability to present a vivid immersive VE to its users while shutting out the physical reality. This is an important capability, as immersion can increase the likelihood of a user feeling as if he or she is physically present in a digital space, which in turn can increase, among other things, the feeling of for example scale in a virtual house and thus the communication and collaboration between for example architects and laymen clients in digital spaces (Colbert et al., 2016).

Researchers and scientists have therefore tried to make technologies more immersive by developing hardware and software that to an ever-larger extent shuts users off from the surrounding environment – physically and mentally. An early version of head-mounted displays was developed in 1965 by an early pioneer within the field of immersive technologies. The head-mounted display was so large and heavy, though, that it had to be mounted to the ceiling, and users often expressed their fear that it would break and cause them injuries (Cummings and Bailenson, 2016).

During the 1990s, entrepreneurs and scientists had yet another go. While the technology had become more immersive through 3D graphics and higher resolution displays, head-mounted displays were still heavy and strenuous for the users. In addition, the hardware required to run the immersive VEs could easily cost 30.000 $, placing it out of reach for the average consumer and organization. As a result, more immersive technologies remained a hype and were primarily confined to researchers.

However, since the beginning of the 1990s, the technological development has resulted in more powerful computers and smaller sensors and displays. And more importantly, the average consumer or organization can today, or before long, afford to buy and use cheaper head-mounted displays.

3.2.1 What determines immersion?

As mentioned, immersion is a technology's ability to shut a user off from the surrounding environment, and any given technology's ability to deliver immersion can be referred to as *system immersion* (referred to as immersion going forward) (Slater, 1999).

These factors, inclusion, extension, and a surrounding and vivid illusion of reality to its users, all increase the likelihood of immersion. However, immersion is not only determined by the display technology, it also depends on e.g. the hardware setup as a whole and the software running on it.

Specifically, the *inclusiveness* is dependent on both the hardware and the software. Inclusiveness is the degree to which a user notices the display while having it on her head. For example, if a client is looking around in a 3D-modeled house, having a head-mounted display on her head but constantly made aware of not being in the virtual house due to a cable that hinders her head movements, the inclusiveness of the head-mounted display is limited.

The *extensiveness* refers to the range of sensory modalities that are accommodated by the system. For example, if a head-mounted display covers both the auditory and the visual sense the immersiveness of the system is potentially more extensive than that of a more simple head-mounted display that only covers the visual sense.

The *surroundingness* depends on the field of view of the head-mounted display (hardware) as well as the immersive VE (software). Specifically, if these allow the user to look around in a panoramic fashion (e.g. being able to see 180 degrees), rather than providing only a limited view (e.g. being able to see 90 degrees), the former technology is more immersive than the latter.

The *vividness* is, to a large degree, determined by the display and by whether it is capable of showing a relatively high-resolution image to the user. However, the vividness is also very much dependent on the hardware that facilitates the immersive VE and its capability to, for example, render something realistic or believable to the senses of the user.

Besides these four factors, another two were mentioned by Slater and Wilbur (1997) that are not directly tied to the display of information, namely proprioceptive matching and plot. The *proprioceptive matching* is activated when the user can perceive and move around in the immersive VE by relying on the same motor mechanisms as he or she would rely on in actual life. In other words, the degree to which the user can use the same body movements in the digital environment as she would do in real life. For example, if the immersive hardware setup can track the movements of the user in such a way that the avatar's head is moving when the user's own head moves in real life, the level of immersion increases compared to e.g. looking around using a controller. Lastly, the *plot* or content is mentioned as an important factor. This factor is mostly determined by the immersive VE produced by the head-mounted display. Specifically, the plot is determined by the degree to which the immersive technology can present a storyline in the digital space that is separate from any cues in the physical world. In addition, the user should be able to interact with the VE so that the user can influence the VE, e.g. the material of a house modelled in a VE (Slater and Wilbur, 1997, p. 4).

In short, the following factors play an important role for users to become immersed in a VE: the inclusiveness, extensiveness, vividness, its ability to let the user move around as he or she would in real life (proprioceptive matching), and the plot or content. Therefore, the increased feeling of being immersed ties to the development of better and cheaper hardware as well as software. Consequently, going forward in this thesis, when mentioning immersive technologies, they relate to both the hardware and the software as both of these aspects are important to consider when trying to understand the ever-increasing immersiveness of VEs and technologies.

Key concept(s)	**Definition(s) and explanation(s)**
Immersive technology	For the sake of clarity, going forward in this thesis, immersive technologies refer to both the head-mounted displays and the digital spaces produced by the displays.
Immersion	The extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant.
Inclusiveness	The degree to which the immersive technology, like a head-mounted display, is free from signals that indicate the existence of the device.
Extensiveness	The range of senses that is covered by the immersive technology, like a head-mounted display. For example, the visual and auditory senses.
Surrounding	The degree to which the display is capable of showing the virtual environment to the user in a panoramic view rather than in a narrow field of view.
Vividness	The resolution, fidelity, and variety of energy simulated within a particular modality. For example, the visual and color resolution of the head-mounted display or the quality of the sound created by it.
Proprioceptive matching	The immersive technology, like a head-mounted display, should be able to match and project the user's physical movements into the virtual environment.
Plot	The extent to which the virtual environment in a particular context presents a storyline. In this case it is more relevant, however, that the user should be able to interact with the virtual environment.

Table 5: Key concept(s) used in this section.

3.3 Technology: the missing materiality of immersive technologies

The technological aspect of immersive VEs is critical in order to understand how the immersive experience is created. Building on Slater and Wilbur's (1997) seven factors of immersion, hardware and software immersion refers to the extent to which any given hardware and software can match a user's proprioception and create a believable plot, while delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human user.

Despite the importance of both hardware and software immersion, an analysis and subsequent coding of the 120 articles reveal that most of them only include the software when analyzing the effect or role that the immersive technologies have on users' feeling of immersion (see Figure 3).

For example, by emphasizing the role that three-dimensional space plays for the immersion and presence of users (Goel et al., 2011; Saunders et al., 2011). Or by focusing on avatars' influence on users' feeling of immersion in a virtual environment through the concept of embodiment (Davis et al., 2009; Schultze, 2014, 2011). While 12% of the articles briefly mention the immersive hardware setup, e.g. as part of the experimental setup, the articles do not account for the hardware during the analysis (O Riordan et al., 2009; Suh et al., 2011).

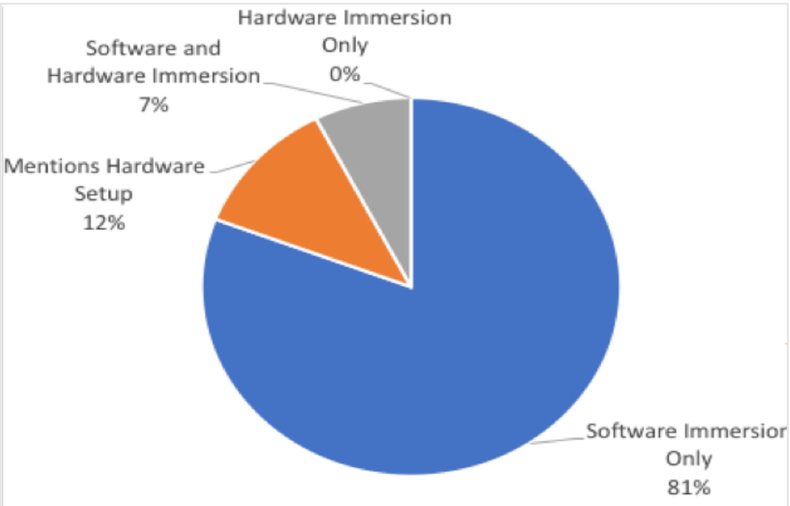


Figure 3: Types of immersion

By only accounting for the software in their analysis, the materiality in the most literal sense – the "physical" matter and form of immersive technologies, like head-mounted displays, or other types of displays – is reduced to the software or the digital aspects of artifacts. While the software is an important aspect to investigate, how information is displayed and the technologies used to display information, as well as the materials and the form of those technologies, are equally central in order to understand whether or not a technology like head-mounted displays, as well as its related hardware and software, is immersive in any given context (Leonardi, 2012).

One reason for the lack of focus on materiality is that 61% of the articles have conducted their analysis on the level of the individual. Specifically, they tend to analyze their data by focusing on the individual and the psychological aspects of individuals and their perception of immersive technologies. The most dominant themes at the level of the individual are adoption, acceptance, use, and continued use of immersive technologies. Most the studies are quantitative, and the Technology Acceptance Model by Davis is the theory most frequently used (Davis, 1989). Therefore, these papers tend to focus on users' perception of immersive technologies. For example, by looking at the acceptance and use of virtual worlds in business settings Nardon and Aten (2012) investigated how employees' understanding of virtual worlds influence their judgments of the value of the immersive technology. The authors analyzed their data qualitatively in the setting of a large IT company that was about to adopt virtual worlds for collaboration. Their analysis resulted in the discovery of three mental interpretations of virtual worlds: virtual worlds as a medium, virtual worlds as a place, and virtual worlds as an extension of reality. The authors associated these mental categories with different criteria for assessing the value of virtual worlds in a business setting. Some of the values of using virtual worlds in this type of setting was increased access to otherwise scarce technical expertise through collaboration with colleagues located in different geographical regions. Virtual worlds could in addition also help companies to be more cost-effective through the holding of virtual instead of physical events. However, other employees also noted that they are amusing but not of any real value to work-related issues. The authors concluded that whether or not an immersive technology is accepted varies and depends on potential users' interpretations and mental categorizations. However, due to the focus on the mental categories of individuals, little is mentioned on the context and whether or not the materiality of the virtual world has an influence on the judgments made by the employees.

Many of the articles of this type that focuses on the individual were published when the interest peaked between 2007 and 2012. Another often used theory that focuses on the individual, or the cognitive aspects of being immersed, is Csikszentmihalyi's theory on flow, the second-most used and cited theory (Csikszentmihalyi, 1990). Flow can help to describe a mental state of complete engagement. Nah, F. et al. (2010) have for example used the theory of flow to better understand the positive effects that Second Life, a virtual world, can have on brand equity. Another prevalent and important theory of immersive technologies is that of presence. Because of the wide-spread use of this theory in other literature streams outside IS, many different definitions exist – some focusing more or less on the individual than others (Schultze, 2010). However, in summary it describes a psychological state where VE, and the objects within that environment, is experienced as physical and an actual environment (Lee, 2004). Franceschi, K. et al. (2009) have for example used theories of presence to explain why virtual worlds, under some circumstances, can increase learning.

However, some scholars have made strides towards including the material aspects of immersive technologies as well. In particular, nine articles directly recognize or analyze the influence or effect that both the software and hardware can have on immersing its users. For example, by using two projectors and a pair of 3D glasses, Boese, M. et al. immersed geology students in a 3D immersive VE (Boese et al., 2009). In their article, they look into how this immersive technology can contribute to the success of students by showing 3D visualizations of realistic maps of rock structures. This helps the students develop a spatial intuition to understand geological processes better. The students in turn enhanced their learning outcomes as well as gained an improved acceptance of the technology. While Boese et al. (2009) do include the technological aspect, their view on the material is a rather static one. In particular, by applying the technology acceptance model, they cast an essentialist light on the immersive technologies. By employing an essentialist perspective on a subject matter, they assume that the technology's immersive capabilities identified are retained no matter the context. Hence researchers tend to downplay the emergent capabilities that immersive technologies can gain in their context of use (Schultze, 2010).

In a literature review on presence and embodiment, Schultze (2010) recognizes and mentions the potential role displays can have on users feeling a sense of presence in an immersive VE, and also notes the aforementioned bias in theories on presence and embodiment to be essentialist (Schultze, 2010). To mitigate these trends, Schultze and Orlikowski (2010) acknowledge both the material, the hardware, and the software, by suggesting a performative lens in the research of virtual worlds and thus immersive technologies. By applying a performative lens to the field of immersive technologies, the authors argue that the emergent aspects of virtual worlds and their implications for organizations will be better understood. A performative lens is useful as it challenges the existence of independent objects with fixed properties and boundaries of immersive technologies like virtual worlds. They argue that a performative lens focuses attention on situated and relational practices of immersive technologies. A performative lens can help to challenge the boundaries between the virtual worlds and humans. They provide an example, in which a user of a virtual world did not care whether her actions were taken in the virtual or the physical world but cared more if they were meaningful or not. This way they illustrate that the boundaries of e.g. the physical and the virtual world are emergent and relational and cannot be drawn in practice. In a later empirical article, Schultze (2011) has for example used a performative lens (Barad, 2003;

Orlikowski, 2007) to identify the social and material practices of avatars and how, among other things, the agency of the human and the material practices blurs when users walk around in an immersive VE (Schultze, 2011).

To summarize, a performative lens can be used to question assumptions that immersiveness is intrinsic to immersive technologies, like virtual worlds or head-mounted displays. Further, a performative perspective could also explore whether, how, and when these properties or capabilities might emerge in the interaction between humans and technology. However, by arguing that the boundaries between the virtual and the physical world are emergent, less focus is given to the materiality of the immersive technologies – that is the hardware that actually facilitates the virtual worlds.

Furthermore, the above-mentioned articles primarily operate on an individual level or by focusing on the relationship between the individual and the technology. Articles operating on different levels of analysis than the individual do not incorporate a performative lens but predominantly utilize theories that focus on the human.

In particular, 13% of the articles are operating on a group level of analysis. Venkatesh et al. (2012) have for example examined the value of virtual worlds and their use for team collaboration.

Around 8% of the articles are looking into the organizational aspects of immersive technologies. For example, Mueller, J. et al. (2011) published an article that investigated the impact of virtual worlds on knowledge and knowing processes across an organization by employing a practice perspective (Brown and Duguid, 1991; Michael, 1966; Nicolini et al., 2003).

However, only 1% of the articles, or two articles, have analyzed interorganizational relationships. One of the articles is an editorial which explores literature on workplace collaboration within and between organizations (Boughzala et al., 2012). The second article, by Gal et al. (2008), investigates the introduction of 3D-modelling technologies and how they act as a boundary object between organizations in the architecture, engineering, and construction industries.

Lastly, 3 articles, or 2% of the reviewed articles, have been investigating immersive technologies from a societal perspective. For example, Yang, S. et al. looked at how stock markets perceived the future revenue streams from many different virtual worlds in a two-year period from 2006 to 2008, with the intent to assess the value proposition of virtual worlds (Yang et al., 2012).

To summarize, IS scholars have to a great extent black-boxed or ignored the effect that hardware can have on immersing its users, but a recent interest in a more relational ontology holds the possibility of considering the materiality of hardware. In addition, an individual level of analysis is prioritized over e.g. an organizational or interorganizational perspective.

3.4 Summary

After reviewing the artifact and the research approach of 120 articles on the topic of immersive technologies in IS, I find it evident that IS researchers have prioritized certain aspects over others. The typical paper on immersive technologies has studied immersive VEs based on software immersion.

In addition, the level of analysis is heavily skewed towards the individual. This choice goes hand in hand with an overwhelming focus on adoption, use, and continued use, as indicated by the frequent use of Davis's Technology Acceptance Model (1989) which is measured quantitatively through survey data.

This typical paper can be contrasted with the broader organizational or societal effects that immersive technologies are starting to have on the professional community, as immersive technologies are preparing to make their entrance into industries such as retail, architecture and construction, and healthcare. In short, after reviewing 120 articles on immersive technologies within the IS discipline, I conclude that significant gaps exist. In particular, IS research seems out of touch with the technological developments of more immersive hardware such as head-mounted displays and the use of it in professional settings.

These potential objects of study are so far largely absent from the existent research on technologies within IS. Thus, more research within the field of immersive technologies needs to focus on either the organizational, the interorganizational, or the societal level of analysis.

In the following chapter I therefore introduce a review of organizational routines literature and how they view technologies. In doing so, my main argument is that organizational routines can help to understand how and why more immersive technologies are not playing a bigger role outside the entertainment industry, as it puts focus on organizational aspects as well as introduces a performative perspective which is needed in order to account for the material aspects of immersive technologies.

4 Theoretical background

In this chapter I present the theoretical background of this thesis: organizational routines theory and the imbrication lens.

First, I describe how organizational routines theory perceives technology. With this I want to provide a way to theorize and map out how exactly head-mounted displays, and its related hardware and software, are enrolled or not enrolled into organizational routines, by focusing on the agency and repetitive patterns of actors and technologies in organizational routines.

Next, I conclude this chapter by introducing the imbrication lens with which I aim to extend and complement organizational routines theory's view on technologies. Specifically, the imbrication lens focuses in more detail than organizational routines on the influence that head-mounted displays, and its related hardware and software, have on organizational routines and vice versa, while preserving a focus on the role of materiality.

Together, these theories will show how I can contribute to a better understanding of how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

4.1 Organizational routines: why are artifacts relevant?

Organizational routines have for a long time been regarded as an essential feature of organizations as much of the daily work done by humans and technology in organizations is somehow connected to routines (Feldman and Pentland, 2003; Nelson and Winter, 1982). So, in order to understand a technology and its influence on organizations, organizational routines are an important concept to look into.

Organizational routines are repetitive, recognizable patterns of interdependent actions, carried out by multiple actors (Feldman and Pentland, 2003, p. 96). This can for example be an organizational design routine in which an architect creates multiple types of buildings but carries out the same actions more than once (repetitive), e.g. choosing a color of the house or designing windows. The recognizable patterns refer to the core actions that constitute specific types of organizational routines. For example, an organizational design routine in an architect company always involves actions such as the opening and creation of a new file in a CAD program. The interdependent actions denote the sequence of actions in the organizational routine which are dependent on each other. And these actions do not only refer to immediate actions in the near vicinity of the architect, they can also refer to actions mediated through technology or actions that are part of another routine completely. For example, the architects and engineers involved in the organizational design routine can sit next to one another but do not have to. Their actions can become interdependent through for instance the sharing of a file, e.g. an engineer that needs to check the electric installations in a house designed by an architect (Feldman and Pentland, 2003). And lastly, multiple actors need to be involved in organizational routines.

As implied, organizational routines can play an important role in organizational routines as they can, among other things, influence, whether or not routines emerge and persist by destabilizing recognizable patterns of interdependent action, and/or support or prevent coordination among organizational communities and functions (D'Adderio, 2011, 2001). Or, they can play a key role in a firm's routines to be both efficient and flexible, leading to, among other things, the firm's innovative capabilities (Adler et al., 1999). In short, because routines are embedded in the context, organizations and technology are closely weaved together in organizational routines (Nelson and Winter, 1982).

Two important streams of literature within the organizational routines literature are the capability and practice perspectives (Parmigiani and Howard-Grenville, 2011). Many scholars within both perspectives have suggested that organizational routines are well equipped to understand why artifacts sometimes matter a great deal while at other times they do not (Parmigiani and Howard-Grenville, 2011; Pentland and Feldman, 2007). While this thesis mainly draws upon literature from the practice-based perspective, the view on artifacts that the organizational capability literature has can contribute a great deal to the practice perspective.

The following section explains in more detail how I will approach this matter by briefly reviewing how each perspective views artifacts in literature on the two research perspectives. I do this with the intent of showing how organizational routines theory can help to map out how exactly the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

Key concept(s)	Definition(s) and explanation(s)
Organizational routines	Repetitive, recognizable patterns of interdependent actions, carried out by multiple actors.

Table 6: Key concept(s) used in this section.

4.1.1 Artifacts and organizational routines: the capabilities perspective

The organizational capabilities research stream, as identified by Parmigiani and Howard-Grenville (2011), is theoretically based on organizational economics. Organizational capabilities perspectives view routines as a “black box” because their main interest lies in understanding what routines accomplish for any given organization in terms of performance by for example mapping the technical and economic factors of routines (Parmigiani and Howard-Grenville, 2011; Pentland and Feldman, 2005). For example, Adler, Goldaftas, & Levine (1999) looked into what mechanisms or routines firms use to be both efficient and flexible, while Peng, Schroeder, and Shah (2008) identified the routine components of improvement and innovation capabilities. When routines are treated as a black box, both the aforementioned examples help to understand capabilities that could increase the performance of any given firm.

Different types of definitions of organizational capabilities exist depending on which research stream you ask. However, scholars agree that organizational routines are a vital part of these capabilities (Parmigiani and Howard-Grenville, 2011). For example, according to Dosi and his colleagues (2008), organizational routines are the foundation of capabilities (Dosi et al., 2008, p. 1167), while Collis (1994) sees capabilities as being social routines that impact the level of efficiency with which an organization can transform an input into an output (1994, p. 143). Lately, scholars suggest that routines as well as coordination processes are important underlying mechanisms for capabilities – the so-called microfoundations of capabilities (Abell et al., 2008; Gavetti, 2005; Teece, 2007).

In the organizational capability perspective technologies have played an important role when for example trying to understand the economic performance of organizational routines. This can be attributed to, among others, Nelson and Winter (1982). In particular, when they laid down the foundations for the organizational capability perspective on organizational routines, they explicitly mentioned the importance of including the context and the surrounding technology. Consequently, artifacts are often regarded in a concrete manner that is often specific to certain types of routines and industries, which stresses the limitations of generalizing across organizational contexts as well (Parmigiani and Howard-Grenville, 2011, p. 445). For example, through the concept of complex product systems (CoPS), Davies and Brady (2000) focus on industry-specific technologies that are particular to high-technology and high-value goods like for example high-speed trains and IT systems (Davies and Brady, 2000, p. 931; Dosi et al., 2008). In this manner, the capability perspective includes technology and their specificity into their equation when trying to explain how capabilities and therefore organizational routines are shaped (Parmigiani and Howard-Grenville, 2011).

In short, the capability perspective is useful when you want to understand how a technology can influence any given routines and thus an organization's performance. Specifically, the capability perspective is relevant if you want to answer research questions that are descriptive, predictive, or comparative. A descriptive question could be a "what" question that identifies e.g. the production rate of organizational routines while a predictive question could aim at e.g. identifying indications of the production rate increasing or decreasing over time (Pentland and Feldman, 2005, p. 801). It is possible to answer these very relevant questions because the capability perspective view routines as a black box which allows the user of such a perspective to e.g. predict future or explain current outcomes of routines (Pentland and Feldman, 2005).

As with any theoretical lens, the capability perspective has some blind angles. In particular, by focusing on the outcome of organizational routines, the capability perspective shifts focus away from the inner workings of organizational routines and the artifact. In the following section, I will therefore look into how the practice perspective complements the capability perspective by opening up the black box of organizational routines and artifacts. In particular, the practice perspective shows that organizational routines and artifacts are not static entities producing certain outcomes that can be determined beforehand. On the contrary, they, actors and artifacts, have the ability to act and therefore often work in unintended ways which have vital implications for the performance of routines, among other things. However, I will also argue that the capabilities view on artifacts can be a helpful reminder for the practice perspective on how to conceptualize artifacts (Howard-Grenville and Rerup, 2016; Howard-Grenville, 2005; Parmigiani and Howard-Grenville, 2011). I argue more precisely that the capability perspective's tangible view on artifacts can help to inform the practice perspective to better understand the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. Despite a recent conceptual and methodological move towards the performances of actors and artifacts, scholars within the practice perspective tend to underrate what is empirically observable, viz. the actors and technologies. In their eagerness to portray the performances of humans and technology, it seems that materiality is put in the background, which is especially prominent in their investigation of digital artifacts due to, among other things, the difficulty in conceptualizing and identifying the matter of the digital – a point scholars placed outside the organizational routines perspectives have argued as well (Leonardi, 2012).

4.1.2 Organizational routines from the practice perspective

The practice perspective opens up the black box of organizational routines with the aim of understanding how organizational routines operate, are reproduced or changed as actors (humans and technology) enact them through their combined performances. This perspective is mainly based on Feldman and Pentland (2003), where they conceptualize organizational routines as consisting of two aspects – a performative and an ostensive aspect, neither of which can exist without the other. The performances of organizational routines are context dependent and refer to the actions that architects, engineers, and other people carry out at a specific time and place. And when the performances are repeated multiple times, e.g. when they design a house, the architects and engineers might form an generalized idea of the organizational routines, the ostensive patterns, which they could then refer to as an organizational design routine (Feldman and Pentland, 2003, p. 101). See Figure 4 below.

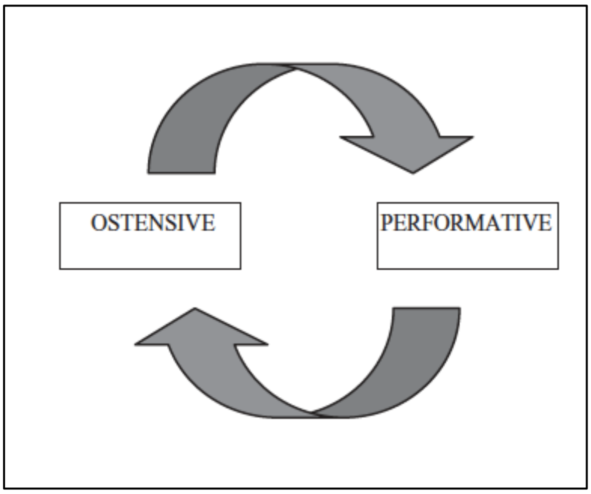


Figure 4: An organizational routine and its parts (D'Adderio, 2011, p. 224).

Importantly, the two aspects, the ostensive patterns of actions and their performances, constitute each other and cannot be separated in practice. This is because actors in an organizational routine use an ostensive pattern of actions to either guide what performances should be taken in the future or legitimize their past performances, and lastly as a reference point that helps actors to make sense of their current performances. To elaborate: An actor should be able to use the ostensive pattern as a way to realize what performances should be taken in the future. For example, by looking at her colleagues, a newly employed engineer can identify a pattern in their performances and use them to guide her future actions in the organizational routine she just became part of. Alternatively, actors can also use an ostensive pattern to make sense of and legitimize their performances retrospectively. If an architect for example doubts whether or not her newly designed door is fireproof, and this aspect is an important part of the organizational design routine she is part of, she can use the ostensive pattern of an organizational routine to explain her previous actions to other colleagues. This way, she can make sense of her pattern of design actions retrospectively while also potentially legitimizing her actions as being part of the organizational design routine. The last thing actors in an organizational routine can use the ostensive pattern for is as a point of reference that helps them to make sense of their performances in the present. A newly employed architect could for example doubt what type of windows he should model a building with. However, by remembering a conversation with one of the other architects, he suddenly remembers what types of windows they prefer for this project, and by remembering this ostensive narrative he knows what to do next in the organizational design routine he is part of. In this manner, actors can use an ostensive pattern of actions to identify their own actions as being part of that organization, in turn making sense of their current actions. In short, an ostensive pattern of actions can help actors in organizational routines: to guide what actions should be taken in the future and to make sense of their current and past performances.

Just as the ostensive pattern plays an important role for the performances of actors in the organizational routines, the performances play an equally important role for the ostensive patterns in organizational routines. The performances influence the ostensive pattern through the creation, maintenance, and modification of it. An ostensive pattern is created when it is repeated multiple times and subsequently recognized as a pattern. Dislodged collections of performances therefore do not constitute an organizational routine – it needs to be recognized as a pattern of actions (as an ostensive aspect) by the multiple actors who are a part of the organizational routine. This way, the two aspects of organizational routines constitute each other. When for example an architect repeatedly designs a house using a head-mounted display, the new types of performative actions done by the architect can result in a new type of ostensive pattern, but only if it is recognized by the other actors who are a part of that organizational routine. The ostensive patterns of the other actors are never the same, but the actors need to have and recognize a core set of performances that make the ostensive pattern recognizable. Another important way in which the performances influence the ostensive pattern is by maintaining the ostensive pattern. That is, by simply performing a core set of recognized actions, the ostensive pattern of an organizational routine is maintained – and vice versa. If no one over time uses for instance head-mounted displays in an organizational routine, the ostensive patterns that it is part of, e.g. a more immersive organizational design routine, will vanish. Lastly, performances can also play an important role in the modification of existing ostensive patterns. If an architect's computer for example breaks down during the process of designing a house, she might choose to modify her existing performance of the organizational design routine by using pen and paper instead. This in turn might change the ostensive pattern if she persists and this form of designing is recognized by the other architects.

As exemplified in the above ways, the performative and ostensive aspects of organizational routines constitute each other.

4.1.3 How a technology becomes part of an organizational routine

Any given artifact, or technology, can become part of an organizational routine if it is enrolled and retained in the ostensive pattern of an organizational routine. Or, to be more precise, if the actors see the technology and what it does as a relevant capability, the technology, and what it can do, might become part of the story of an organizational routine. For example, if a head-mounted display's capability to let users look around in an immersive VE using one's head is seen by actors as a relevant thing to do, the technology and this ability might become part of the story (ostensive pattern) about how they for instance design things in an organizational design routine. To better understand how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines, it is important to understand how organizational routines are capable of changing.

That is, in contrast to the capability perspective, organizational routines are not only seen as stable. Instead they are seen as something that on the one hand can be stable but on the other hand is ever changing because organizational routines have agency. This paradox refers to the observation that organizational routines on the one hand often consist of the same repetitive pattern of actions, its ostensive pattern, while on the other hand, the actors have to adapt their performances, which are guided by their ostensive pattern, to the context in which they are performed. And sometimes these adaptions can become a variation which ends up being recognized as part of the actors' common story of the organizational routines (the ostensive pattern).

In particular, when a variation, which might encompass a new technology, becomes part of the ostensive pattern of an organizational routine, it typically starts out as a dislodged performance which then might end up being selected, and eventually retained in the ostensive pattern of an organizational routine (Feldman and Pentland, 2003; Pentland et al., 2012). To elaborate this aforementioned process of change starts when a variation occurs. As mentioned, a variation occurs naturally in organizational routines as actors continually have to adapt their idea or narrative of an organizational routine (their ostensive patterns) to the local context as they perform any given organizational routine. However, sometimes a variation is selected by an individual actor which was not seen as being part of the organizational routines by that actor and the other actors participating in that organizational routine. If the actors all recognize that this new variation should be turned into part of the story about how they perform that organizational routine, this selected variation would then be retained in a new or modified ostensive pattern. And consequently, the actors would then use this modified or new ostensive pattern to: guide their performances after, account their performance after, or refer their actions to. This way, when a variation is selected and retained, it therefore either creates a new ostensive pattern or modifies an existing ostensive pattern.

In Feldman and Pentlands initial theorizing of organizational routines, artifacts were only implicitly recognized (D'Adderio, 2011; Feldman, 2000; Feldman and Pentland, 2003) (see Figure 4). But as will be explained in the following section, artifacts and their relations to the performative and ostensive aspect were made clearer at a later stage.

4.1.4 The conceptualization of artifacts in organizational routines theory

The capability perspective conceptualized artifacts as too solid or as a black box without any agency, while Feldman and Pentland's (2003) initial conceptualization of artifacts, or a lack thereof, made artifacts' role in organizational routines theory somewhat marginalized (D'Adderio, 2011). The motivational focus for Feldman and Pentland's reconceptualization of organizational routines, though, was to a minor degree to understand the role of artifacts in organizational routines. Instead, it was to underline that organizational routines have agency, emphasizing that organizational routines are not only monolithic and stable black boxes, as they have the innate ability to generate change – simply by enacting and performing them. In this manner, their initial aim was to complement the capability perspectives view on organizational routines as a black box and to underline that from their enactment alone, organizational routines can be the source of learning, flexibility, and change in organizations (Feldman, 2000; Feldman and Pentland, 2003).

Artifacts in organizational routines theory was later included, as illustrated in Figure 5 (Pentland and Feldman, 2005, 2008a).

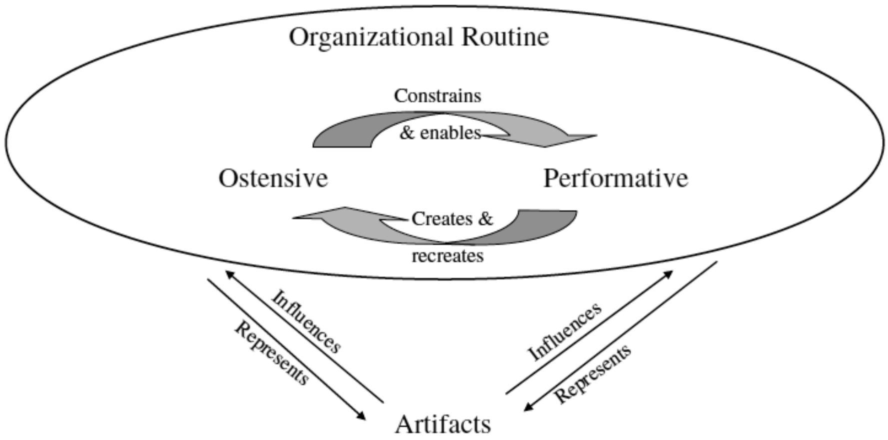


Figure 5: An organizational routine (Pentland and Feldman, 2008a, p. 241).

In their conceptualization, artifacts are the physical manifestations of organizational routines and they have the ability to enable and constrain organizational routines. Artifacts therefore do not play a central role in organizational routines theory. Instead, they can codify certain aspects of the ostensive part of organizational routines, which standard operating procedures are an example of. In addition, artifacts' relationship to the actors' performances is not a one-to-one relationship either. That is, artifacts such as standards operating procedures rarely determine the performances of the actors fully – even though managers often envision this scenario.

Instead, artifacts can be seen as representations or indications of the ostensive and performative aspect of organizational routines. For example, construction projects are often depicted as a process that starts with planning, continues with designing, and ends with construction. However, this process is rarely as linear in practice. Rather, the document (the artifact) that depicts this process only represents an ideal version of the process which helps the many involved actors to communicate and form many different narratives, or ostensive patterns of actions, of how they should perform an organizational construction routine. This way, artifacts represent some aspects of the ostensive pattern of the organizational routine and/or might help to guide the performances of the actors in that organizational routine. But artifacts rarely, if ever, fully determine an organizational routine in the intended way. And because of this, artifacts are located outside of the organizational routine to underline the importance of not confusing the artifacts with the organizational routine itself, as such a conflation can lead to the misunderstanding that artifacts, such as documents, standard operating procedures etc., are the organizational routines or a one-to-one representation thereof.

By placing artifacts outside of organizational routines, Feldman and Pentland also stressed the important point that the introduction of artifacts in an organizational routine does not necessarily lead to them being used by the actors and thus retained in the ostensive pattern of organizational routines. An example of this conflation of the ostensive pattern of organizational routines and its artifacts is also what leads to technological determinism. This is the case, for example, when managers introduce IT systems or standard operating procedures into organizations and then think that the systems or procedures will increase efficiency in a predefined way, or assume that an IT artifact will be used in the intended way (Pentland and Feldman, 2008a).

To avoid the assumption that technologies are a priori enrolled into new performances and retained in ostensive patterns, and to shape them in a predictable and determined way, Feldman and Pentland therefore stressed that artifacts mostly represent or indicate the ostensive and performative aspect as one cannot beforehand be certain if artifacts, once enrolled into organizational routines, will influence them (Pentland and Feldman, 2008a). And if artifacts succeed in being enrolled into organizational routines, their influence is often unpredictable. This was for example supported by Hales and Tidd's empirical study in which they found that the main focus of their study, the implementation of a software-enabled checklist, had little influence on the performances of organizational routines. Instead, rather counterintuitively, verbal stories (so-called non-formal organizational routines) and other artifacts such as PowerPoint presentations and illustrations that supported these stories, ended up as being highly influential on the organizational routines instead (Hales and Tidd, 2009, p. 568). Thus, the main focus of the implementation, a new software-enabled checklist, did not end up having much influence on the organizational routines. Instead, a by-product of it, the PowerPoint presentations and the illustrations, had a more significant effect on the performances of actors in the organizational routines because they allowed for the actors to perform storytelling. And as a consequence, these artifacts ended up being retained in the actors' ostensive pattern instead of in the software-enabled checklist. Thus, while some artifacts might not influence or shape organizational routines and their agency, other artifacts will. And at times, the same artifact might not influence an organizational routine at all while at other times, it is instrumental for how an organizational routine is shaped.

In short, to avoid technological determinism when trying to understand the influence of artifacts on organizational routines, Feldman and Pentland argued that artifacts can "merely" represent organizational routines. To be more precise, the artifacts typically represent a partial picture of the ostensive aspect of organizational routines and only encode specific aspects of actors' performances.

4.1.5 A shift in the relation between artifacts and organizational routines

At a later point, D'Adderio argues to bring artifacts to the center of the organizational routines (2011, p. 198), see Figure 6, with the aim of conceptualizing the relationship between artifacts and organizational routines in a more nuanced way by employing theoretical concepts from other disciplines, such as Actor-Network theory. By introducing concepts from Actor-Network theory D'Adderio show the artifacts become more than neutral representations of action as initially conceptualized by Feldman and Pentland (2003).

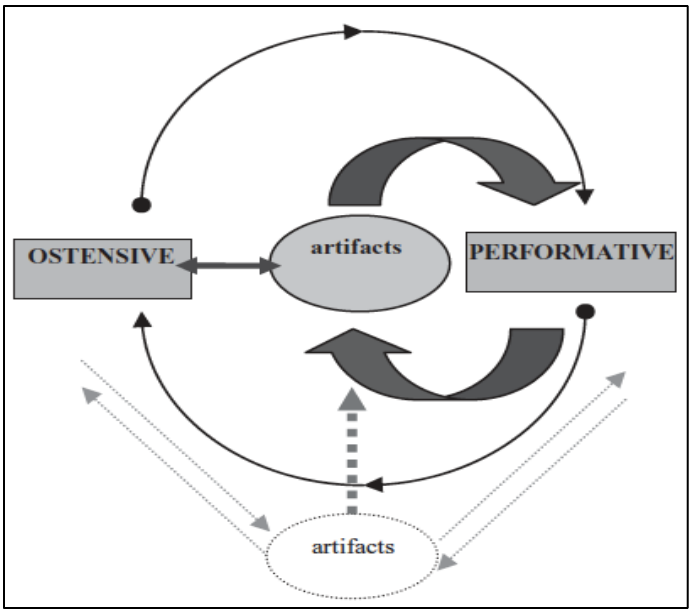


Figure 6: Artifacts moved into organizational routines (D'Adderio, 2011, p. 224).

Instead, artifacts are seen as mediators and start to actively shape and are shaped by humans and other nonhumans as they are enrolled and retained in organizational routines. That is, the representations from the ostensive aspect that actors choose to inscribe into the artifacts are not always randomly chosen. Some aspects can be deliberately left out from the artifacts with the intent of shaping an organizational routine in a specific way. Thus, through a conceptual notion such as inscription, artifacts become encoded with specific assumptions and intentions by other humans and nonhumans. Consequently, focus can be shifted towards the fact that artifacts are not neutral intermediaries of action but mediators that translate actions. Another concept, such as power of default, sheds light on how and why humans use artifacts in a certain way and often blindly follow the default inscriptions and designs of artifacts. Together, such concepts show that artifacts do not merely represent organizational routines or are indicators of it. Instead, artifacts should be seen as something that actively participates in how organizational routines shape and are shaped by artifacts. This is why D'Adderio and since then others as well have argued that artifacts should be moved into a more central role in the theorizing of organizational routines. See Figure 6 (e.g. D'Adderio, 2014; Glaser, 2017; Turner and Rindova, 2012).

These concepts provided organizational routines scholars with more conceptual nuances, thereby acknowledging that performances are mediated – and partially shaped – by artifacts and vice versa. However, while this is an important avenue of research, Howard-Grenville (2016; 2005; 2011) as well as other scholars have pointed out a paradox (Howard-Grenville and Rerup, 2016; Parmigiani and Howard-Grenville, 2011). In particular, because humans and nonhumans are seen as hybrids, who or what does what is not the main focus of attention. Instead, focus is on the actions of humans and nonhumans, actants, which deliberately do not distinguish if it is a human or a nonhuman that is doing any given action (Leonardi, 2012, 2011; Pickering, 1995). At other times, artifacts and technologies are conceptualized as nonhumans and focus is on for example how they are inscribed with certain values or transform actions in specific ways through the concept of translation. While these concepts are important to portray a more nuanced picture of the relationship between artifacts and organizational routines, these concepts tend to overshadow the matter and form of technologies. In particular, these concepts shift focus away from the materiality of technology to the agency of humans and nonhumans, actants. In other words, when organizational routines scholars employ these concepts, they therefore risk shifting attention away from the materiality of technology by focusing on what humans and technologies do together as actants (Leonardi, 2012, 2011; Volkoff et al., 2007).

4.1.6 Keeping artifacts and organizational routines distinct

The introduction of these concepts has provided scholars with the ability to understand the relationship between artifacts and organizational routines in a more nuanced way. However, I assert that it is important to maintain a distinction between artifacts and the performances of human actors in organizational routines, as initially argued (2005, 2008a) and later reiterated by Feldman and Pentland (e.g. 2016). While it is important to recognize artifacts as an active participant in the shaping of organizational routines, and vice versa, by introducing concepts such as actants, there is a risk of conflating from where the actions are coming from – the human or the nonhuman actors, which has also been pointed out by other organizational routines scholars (e.g. Parmigiani and Howard-Grenville, 2011; Volkoff et al., 2007). Furthermore, this can also lead one to focus less on the materiality of artifacts, its matter and form, as the focus is on what the performances of humans and artifacts do (together) while not directly attending to the materiality of artifacts, its matter and form.

These distinctions are especially important to maintain when trying to capture the development of hardware-driven IT phenomena like head-mounted displays, but also in general as information technologies are increasingly becoming more flexible – a development that cannot be captured without attending to the materiality of IT (Leonardi, 2011; Pentland and Feldman, 2007). However, the actual materiality e.g. the form and matter of head-mounted displays, are often portrayed as being intact, or not focused on at all, in turn casting the materiality of technology as mostly static or inflexible.

This is best exemplified with the aforementioned concept of power of default which stresses that people tend to choose the path of least resistance, and while it is in theory possible to change technologies, in practice, this does not happen very often. Or as D'Adderio expresses it: *"…while formal software controls can – in theory – be easily modified or entirely averted, in practice this requires the deployment of resources (e.g. time and software programming skills), which are often unavailable. In these circumstances, the 'power of default' of such artifacts…will prevent adaptation and customization."* (D'Adderio, 2011, p. 216). Thus, by using concepts such as power of default and actants, the focus is shifted away from the materiality of artifacts and technologies to for example the consequences of any given technologies' defaults or to what humans and nonhumans do together (actants). By pursuing such a focus, it seems that the materiality, in the most literal sense, namely the matter and form of technology, is not directly conceptualized. This can in turn lead to people seeing artifacts as being fixed or static because the role that the matter and form of the technology play, which shapes its material agency, is downplayed. Consequently, the materiality of a technology and its potential for change, flexibility, or for that matter inflexibility, is not directly attended to.

This is not to say that technology in itself is flexible or inflexible, as it is embedded in organizations where people, and other artifacts, can have it modified to fit their needs. For example, not all people poses the technical know-how to change the code in existing programs that enhance the software in some way or another. But if the context, people, and other connected technologies “allow” a technology’s materiality to change, this flexibility of its material properties can be decisive in order to understand how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. It is therefore important to include the material idiosyncrasies of the technology by conceptually differentiating between what a technology does and what it is, its matter and form.

Furthermore, the context in which technology exists in is equally important when understanding the role of technology in organizational routines (Parmigiani and Howard-Grenville, 2011, p. 445). The introduction of such concepts as actants seems to have prompted a shift of focus to the material agency in isolation. As a result, organizational routines researchers also tend to underprioritize the surrounding technical infrastructure that the empirically observable technologies are connected with. For example, a software program is likely to be easier for people to change and work around in a software development organization than, say, in a shipping company, due to their professional training but also because of the software and infrastructure they work with. This means that organizational routines scholars should be aware of and not disregard the form and matter of artifact(s) under investigation when conceptualizing technology and its material agency.

To summarize, as this theoretical review of the practice perspective shows, the scholars has taken steps towards giving technology a more prominent and active role in organizational routines theory. However, researchers do portray the technology as being static or inflexible due to a lack of focus on the materiality of technology. In particular, with the utilization of concepts from Actor-Network theory, technology has been given agency. However, as concepts, like actants, do not make a distinction between what a technology is and what it does, the materiality is not conceptualized directly (Leonardi, 2012, 2011). Consequently, the technology, and the other technologies it is connected to, is often cast as being intact or static in the interactions with human performances because its physical properties, its matter and form, and its potential for flexibility/inflexibility are undermined. In relation to my thesis, this conceptualization of technology makes it difficult to map out the influence of head-mounted displays, and its related hardware and software, on organizational routines.

In the following chapter I will illustrate and exemplify in more depth how these tendencies come to light in organizational routines literature, with the intent of introducing an alternative conceptualization of organizational routines and technologies relationship.

Key concepts	**Definitions and explanations**
Performances	The actions taken by actors involved in an organizational routine.
Ostensive pattern	The different narratives or ideas of a routine that the actors in the routine have. Sometimes referred to as ostensive patterns to underline that the ostensive pattern consists of repeated performances or actions that contain the same pattern.
Nonhumans (technology)	A concept encompassing everything that is not human which is often used in Actor Network Theory. In my thesis I primarily use the narrower term technology.
Artifacts	Artifacts are the physical manifestations of the organizational routines which enable and constrain organizational routines. In my thesis I primarily use the narrower term technology.
Variation	A variation in the performances of an existing organizational routine which might be selected and become part of the ostensive pattern of an organizational routine.
Selection	A variation that is selected to become part of the ostensive pattern of an organizational routine.
Retention	A variation that becomes part of the ostensive pattern of an organizational routine. The ostensive pattern should then help the actors in one or more of the following ways: They should be able to use the ostensive pattern as a way to guide their future performances. Or they should be able to use the ostensive pattern as a way to legitimize their past performances. Lastly, they should be able to use the ostensive pattern as a way to make sense of their current performance.
Actant	The possible actions of humans and/or nonhumans (e.g. technology).

Table 7: Key concept(s) used in this section.

4.1.7 Digital and non-digital artifacts in the practice perspective on organizational routines

To exemplify how organizational routines have been investigated and conceptualized, I will build on and extend Howard-Grenville et al.'s (2016) review of organizational routines literature review. In particular, in the following section I review articles within the practice perspective of organizational routines literature that focuses on digital technology as this type of technology are the main focus of my thesis. With this focus, I aim at showing how current literature has come a long way to understand the relationship between technologies and organizational routines by conceptualizing the agency of humans and nonhumans. However, as I will show in the following paragraphs, there are also tendencies to either investigate inflexible technologies or conceptualize them as such by undermining the role of materiality - the matter and form of technology. With this I aim to show that there is a lack of literature investigating the influence that more flexible technologies can have on organizational routines, which in part has to do with how technologies have been conceptualized.

D’Adderio (2001) investigates CAD visualizations (e.g. 3D CAD models) in automotive and consumer electronics organizations while in a later article, D’Adderio's (2003) focus is on a database – again in the setting of an automotive firm. In the first instance, D’Adderio highlights that the IT programs used are indeed quite flexible. However, it is also mentioned that it is quite difficult for some professions, the industrial designers, to generate the digital models, incorporate feedback, and make changes to the models as the program utilizes an engineering approach, primarily. While the CAD program is flexible, it is stated that it is in practice quite hard to change and therefore acts as a standardizing device that needs to be appropriated and used by the employees. In her second paper, D'Adderio also highlights the rigidity and inflexibility of the software, and how the embedding of knowledge into software and as well as the software itself can obstruct informal actions and flexible behavior due to the software's rigidity and inflexibility.

Thus, in D’Adderio’s articles the technology is something that is mostly used by the employees while she focuses on primarily the inflexibility of the technology. This tendency might have to do with the age of the articles and the type of technologies investigated. That is, as stated in the previous section, technology has today developed into being more modular and reusable, which could have influenced the focus of the author's papers. In addition, while both papers do mention the form of the digital artifacts, little is mentioned about artifacts intercoupling with the surrounding hardware and software and how this intercoupling also changes the employees’ interactions with the artifact.

Volkoff and Strong (2007) have looked into the implementation of an SAP’s R/3 software suite at a multinational manufacturer of precision industrial products and identified: *“When embedded in technology, organizational elements such as routines and roles acquire a material aspect, in addition to the ostensive and performative”* (Volkoff et al., 2007, p. 832). The authors directly address the materiality of the technology and how it shapes the organizational routines and vice versa. In addition, the enterprise information system is seen as configurable, during implementation, but afterwards quite static and inflexible to the degree that it even constrains and changes the organizational routines of the employees, as the ostensive part of the system is embedded in the materiality of the enterprise information system. Important to mention as well, is that Volkoff and his colleagues also note, as a limitation of their study, that research should look into more flexible IT systems which might create fewer constraints for their users.

In another article investigating the implementation of an enterprise information systems, Berente and his colleagues (2016), in the context of NASA, discovered how different elements of organizational routines dynamically adjusted, like shock absorbers, to allow for an otherwise successful implementation of an otherwise rigid enterprise information system, as phrased by the authors. While they do mention that the material is changing, this is mostly due to the employees' ability to adapt and use the IT system in unexpected ways. For example, when employees type in extensive amount of data into a field which is designed for a header only (Berente et al., 2016, p. 9).

The above-mentioned articles thus tend to put the technology in a light that makes it less flexible than its human counterparts. This is in part due to the age of the articles but could also be due to the types of information systems that they investigated, enterprise information systems, which both the studies portray as being inflexible. These information systems might actually be quite hard to for example reconfigure or reprogram and can rightfully be cast as inflexible. In either case, little knowledge is gained on how more flexible information systems might influence how technology influences organizational routines.

The aforementioned articles' primary reason to regard technology as a rather inflexible entity could be the type of information systems under investigation, viz. enterprise information systems. However, the following articles portray technology as inflexible due to their conceptualization of technologies because they employ concepts from the Actor-network theory (Cacciatori, 2012; D'Adderio, 2008; Sele and Grand, 2016), as suggested by D'Adderio and others (2011, 2008). However, in doing so, the aforementioned authors risk to blur where the agency is coming from – that is, from humans or technologies. As previously argued, though, by applying such a focus, the authors make it difficult to shed light on the possible flexibility that the materiality and its matter and form could allow for as the materiality is not directly conceptualized (Leonardi, 2012, 2011).

For example, through the concepts of actants, mediators, and intermediaries, Sele and Grand (2016) show on the one hand *"…how the interactions of organizational routines can be more or less generative…",* describing that the artifact under investigation can have generative effects and therefore material agency. On the other hand, however, *"…by tracing and analyzing how human and nonhuman actors (actants) connect* [organizational] *routines",* the flexible or inflexible material properties of the artifact (e.g. the robot) and *how* these could condition current and future performances of the human are hard to discern as their materiality is put in the background when robots are conceptualized as actants (Sele and Grand, 2016, p. 722).

Another article investigated how and the degree to which standard operating procedures (SOPs), embedded in software, affected organizational routine performances in the context of a semiconductor equipment supplier (Hales and Tidd, 2009). Hales and Tidd (2009) discovered that their software-embedded SOP had relatively little influence on the performances of organizational routines and vividly describe what other artifacts are used to facilitate the embedded SOP as well as the materiality of it. However, focus is mainly on the employees and how they circumvent the wizard, thus showing the dynamic nature of the employees and rigidity of the wizard. Interestingly, though, the artifacts produced as an outcome of the investigated organizational routine, in the form of PowerPoints, were relatively more influential on the performances of the organizational routine. Specifically, these PowerPoints were significant because the employees could use them as storytelling devices – which again shows how employees *use* an artifact (PowerPoints) in a flexible manner, thus illustrating the dynamic nature of the employees against technology as the static counterpart. Finally, due to a focus on these more semiotic aspects of artifacts, relatively little is mentioned on the form and matter (the materiality) of the investigated artifacts and whether the materiality played a role in excluding the wizard of the organizational routines.

Lastly, Glaser (2017) and Spee et al. (2016) investigate the role that Excel sheets play in organizational routines.

In an article conducted in a law-enforcement organization, Glaser (2017) focused on two schedules, in the form of Excel sheets, a cell phone, and a citation booklet, to understand how artifacts are designed to intentionally influence the performances of actors and the dynamics of organizational routines. Glaser focuses on how an Excel sheet is continually modelled and designed or in short – how artifacts are designed to intentionally influence the dynamics of organizational routines.

Spee and colleagues (2016) show how artifacts play an important role in coordinating multiple ostensive patterns. In particular, artifacts were categorized into two types of artifacts, namely *core* (an Excel sheet) and *supplementary* artifacts (brochures, cover e-mails, and notes), which contributed to the supporting, standardizing, and customizing of performances and thus two different ostensive patterns. Supplementary artifacts, created in interdependent organizational routines, were inscribed with certain types of knowledge. Once these artifacts were injected into the focal organizational routine of investigation, they were essential to the coordination of standardization and flexibility between the two organizational routines by logging their knowledge into the core artifact located in the focal organizational routine. Thus, as with the aforementioned article, focus is primarily on the semiotics of these artifacts and how that standardizes two different ostensive patterns. Little is mentioned, though, on the form and matter of for example the hardware and its role in standardizing. Second, they explicitly mention the importance of investigating further the relationship between the core and the supplementary artifacts, thus implying the need to investigate the context and other technologies involved more thoroughly.

In both the Glaser (2017) and Spee et al. (2016) articles, their conceptual focus is predominantly on the contents of Excel sheets and how actors inscribe knowledge into them, which in turn shapes the performative and ostensive aspects of organizational routines. For example, Glaser (2017) shows the flexibility and malleability of a mathematical algorithm embedded in an Excel sheet. However, because Glaser (2017) employs a sociomaterial perspective, without the hyphen between the socio and the material, his focus is on assemblages and inscriptions. According to Cecez-Kecmanovic et al. (2014), this sociomaterial perspective has its roots in Actor-Network theory which sees the human and the material as inseparable (Leonardi and Rodriguez-Lluesma, 2012), making it harder to discern where the actions are coming from and thus the role of materiality in the mutual shaping of the human and material agencies. Both Glaser (2017) and Spee et al. (2016) also employ the Actor-Network theory concept of inscription, which, as mentioned, was introduced by D'Adderio (2011, 2008), to focus on how different worldviews and ideologies can be embedded in artifacts. However, by doing so, focus is shifted to the semiotics of the artifacts. Or more specifically, the content of the Excel sheet. Thus, attention is predominantly on the content of for example the Excel sheets and to a lesser extent on the physical materiality of its surrounding artifacts and how that might influence and be influenced by the human actors in the organizational routines.

Important to mention, though, is that Glaser (2017) acknowledges other aspects than the semiotics of the Excel sheet, indirectly, by stating in the limitations that other technologies could make a different impact on the performances of the organizational routines. That is, a software artifact differs significantly from other types of artifacts like standard operating procedures or more physical machinery.

In this chapter I have shown that authors within the practice perspective of organizational routines tend to either investigate rather inflexible technologies or conceptualize them as such by not addressing the matter and form of artifacts directly, and how artifacts have the potential to be more flexible due to the increased modularity of technologies and/or due to the context in which it is embedded. It is important to investigate the potential flexibility of technologies to better understand how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. To elaborate, the above two tendencies tend to hinder this in the following ways.

First, by utilizing concepts such as actants, the agency of humans and nonhumans is conflated. In turn, authors tend to blur where the performances are coming from as well as the material characteristics of artifacts – that is, the matter and form of the hardware and software – a point that scholars within the practice perspective, such as Volkoff (2007), Robey (2013, 2012), Howard-Grenville (2016; 2005; 2011) and their colleagues, have implied as well. Second, as a consequence, there is a tendency to portray materiality, and its agency, as static and people as dynamic. That is, articles tend to depict the relationship between artifacts and humans as a process where the actors in organizational routines perform their human agency *on* or *with* artifact(s). Or, at other times, by using the artifacts in unanticipated ways. The material properties of artifacts are not directly addressed, or they are seen as rather inflexible. However, technology today is not only static or inflexible but also flexible; not only because of the technology itself but studies have also shown that, especially in recent years, many organizations are increasingly employing in-house developers and other IT competent people that are capable of changing the materiality of IT itself through e.g. programming (Leonardi, 2011). Others have pointed out that IT is also becoming adaptable and increasingly modular as we have entered the LEGO era of IT (Pentland and Feldman, 2007). Both of these blind spots are somewhat related to the third and last point, namely that there seems to be a lack of focus on the context in which these artifacts are situated, e.g. the technological infrastructure in which artifacts are situated, and how it helps to retain some artifacts in organizational routines while un-enrolling others. Thus, artifacts are not necessarily in themselves flexible or inflexible. The flexibility or inflexibility depends on previous technologies that are enrolled and retained in the organizational routines as well as on the other people participating in the organizational routines.

To complement the existing literature on organizational routines, in the following section I will introduce the imbrication lens with which I aim to make a clear distinction between human and material agency. This has the following implications: First, it allows me to conceptualize the matter and form of head-mounted displays directly, as well as the hardware and software it is connected to, because humans and technology are seen as ontologically distinct phenomena. In turn, what a technology is and what it does can more clearly be conceptualized as two distinct phenomena. Consequently, a more dynamic relationship between the human and technology is conceptualized more clearly as the focus on materiality helps to highlight the flexibility or/and inflexibility of head-mounted displays and the hardware and software it is connected to.

Second, by introducing the imbrication lens it allows me to explicitly show how technologies and organizational routines are conditioned by other technologies and actors participating in the organizational routines. In this manner, it directly accommodates technologies and their materiality that are already enrolled in the organizational routines, and which can have an influence on how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

4.2 The imbrication lens

In the following section I present the concept of imbrication to complement the two aforementioned literature streams by sensitizing the theories to the materiality of technology. In particular, the aim is to highlight that the materiality is important to account for as it plays a significant role in people's understanding of whether a technology is flexible or/and inflexible in any given context. Ultimately, it assists in answering my research question: *"How does the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines?"*

The imbrication lens focuses on how the agency of human and technological weave together (Leonardi, 2011). In particular, an imbrication is a conceptualization of the arranging of two distinct elements, human and technology, and how they weave together as they enact their performances. The concept of imbrication was originally conceived by Taylor (Taylor, 2016, 2001). He conceptualized humans and technologies in this manner to underline their interweaving and to stress how they mutually constitute and act on each other. Taylor exemplifies the interweaving and interdependency of humans and technologies by stating that: *"If there were no doctors, there would be no patients, but also vice versa; if no gold then no gold miners, but, inversely, if no miners, no gold."* (Taylor, 2016, p. 1). Consequently, humans and technology weave together to constitute and construct each other.

The word itself, imbrication, also underlines the aforementioned points. To imbricate is derived from the names of two types of roof tiles, the imbrex and the tegula (see Figure 7). By arranging imbrices and tegulae in such a way that they overlap, they create a visible pattern, channels, that can funnel water away from the roof while making it water-resistant. This illustration serves to conceptualize the moment when humans and technologies, imbrices and tegulae, weave together and create a visible pattern. And just like the roof tiles are dependent on each other's differences to create a more solid and waterproof structure, so are humans and technologies. While both have the ability to act, humans and technologies do differ: humans have the ability to form their own intention whereas technologies do not, but technologies are potentially more durable across time and place due to their materiality. Thus, like roof tiles they have different shapes and are made of different materials yet they have the ability to form patterns and integrated structures when they imbricate. As a result, the imbrication lens complements the organizational routines theory by illustrating that humans and technology are ontologically distinct but once they enact their performances, they can become integrated structures and imbricate. And just as with Feldman and Pentland's (2003) theory on organizational routines, but in contrast to most theories on immersive technologies, humans and technologies both have the capability for action.

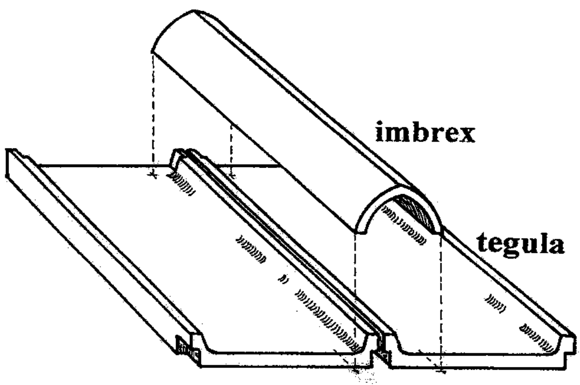


Figure 7: An imbrication of human and technology.

In relation to this thesis, an imbrication could for instance be when an architect (human) puts on a head-mounted display (technology) to look around in an immersive VE with an intention to check the lighting from a specific spot in a virtual house. Once the architect starts to look around in the house using her head, the architect and the head-mounted display start to shape each other's performances. The architect with her intentions and goals and the head-mounted display with its physical and digital matter and form.

As mentioned, the imbrication lens depicts how humans and material agencies interact to create an interlocking pattern, hence the metaphor. This pattern entails that humans and material agencies are influencing each other repeatedly. It starts for example when an architect, who is part of an organizational design routine, sees a constraint in a technology that is enrolled in the organizational routine. This in turn leads the architect to change the technology. This new or changed technology then affords a new performance which again will change the organizational routine. This interlocking pattern is what the imbrication lens tries to depict.

And the outcome of these imbrications is an infrastructure of existing and new, modified or changed organizational routines and technologies. That is, when the technology is initially seen as constraining, it creates a new/changed infrastructure in the form of a new/changed technology. And once the technology is changed or a new one takes its place, a new affordance potentially becomes available, which eventually leads to a new infrastructure in the form of a new/changed organizational routine. This new infrastructure will then condition future imbrications of human and material agency. The following section exemplifies and illustrates in more detail (see Figure 8) how human and material agency imbricate to create an infrastructure of technologies and organizational routines.

4.2.1 The imbrication process: how humans and the material agencies interact

The process of change starts when one or more architects starts to realize that the current way of designing artifacts is e.g. not effective enough because it produces too many design errors (the first oval shape). This is a consequence of their current experience with using a monitor (the horizontal arrow), which then initiates imbrication 1 (human → material). Based on that experience, two architects enact their human agency and set a new goal (the hexagon shape) – they want to reduce errors in the organizational design routine. And with this new goal in mind, they see the current technology that they use to design 3D models, a traditional monitor, as a constraint. The consequence of this new goal is to change their current technology (the vertical arrow) by adding a head-mounted display to supplement their traditional display when designing artifacts (the human agency), thus changing the technology (the rectangular shape).

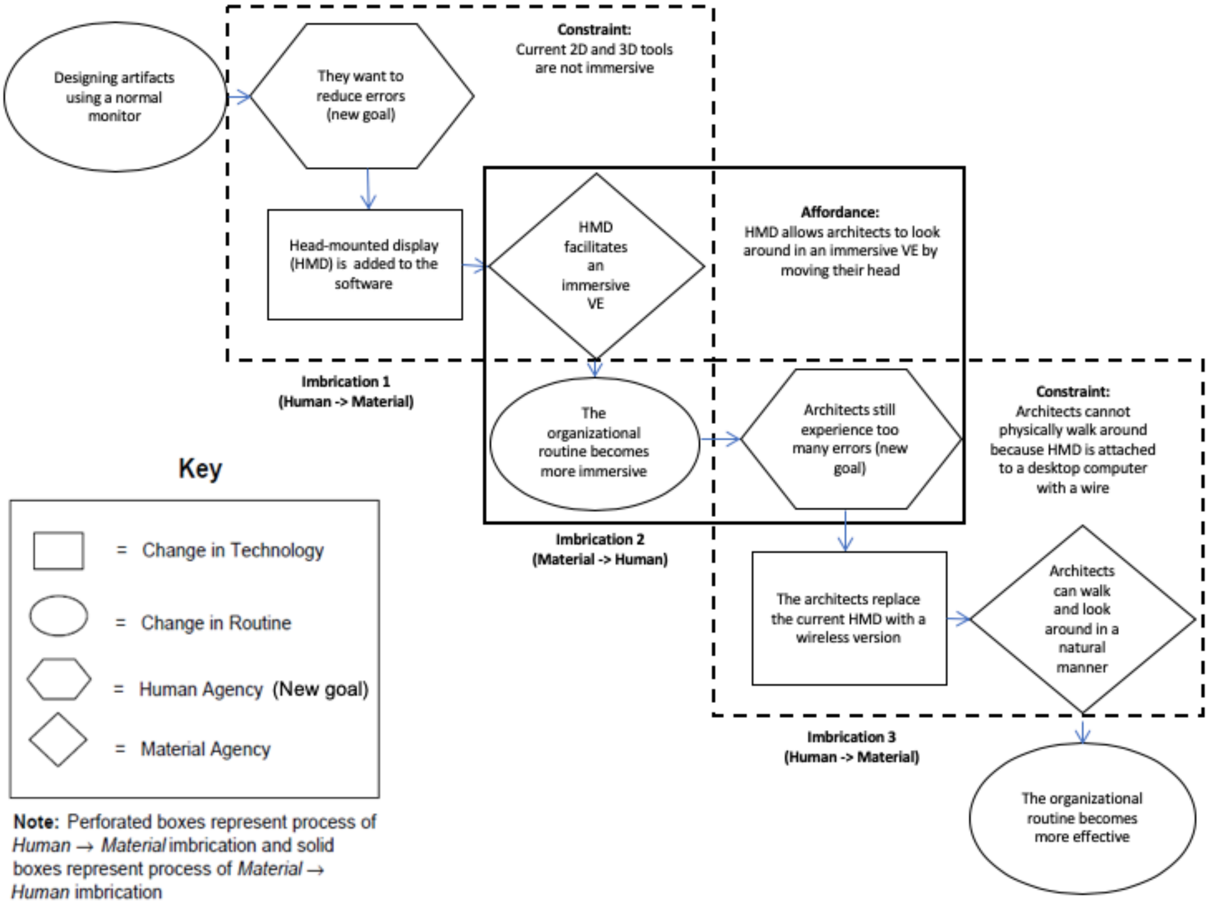


Figure 8: A simple example of Leonardi's (2011, p. 158) imbrication process.

A consequence of adding this new head-mounted display to their current way of designing 3D models (the horizontal arrows) is that they are now able to become more immersed because the material agency of the head-mounted display (the rhombus shape) facilitates a more immersive VE by for example affording them to look around in a natural manner when immersed in a 3D model. This allows the architects to identify more errors when they design 3D models. And because, in this case, the other actors involved in the organizational design routine see this way of designing as a more productive way to design as they can identify errors early in the design process, the consequence is (the vertical arrow) that the performances, which the head-mounted display is part of, are repeated and recognized by more than one actor, thus changing the organizational design routine (the second oval shape) by being retained in an alternative ostensive pattern of the organizational routine. If the architects at a later point identify problems with the head-mounted display that constrain them in for example legitimizing the use of the head-mounted display to their colleagues, they will then see it as constraining. Consequently, they will start to act and form a new goal that aims to resolve this constraint.

In these ways, the head-mounted display that affords looking around, can initially change the organizational routine's ostensive pattern, if recognized. And once the head-mounted display has changed the organizational routine (by creating a new ostensive pattern or modified an existing one), it can become a constraint for the organizational routine as the new affordance of the head-mounted display introduces new goals. Consequently, as the head-mounted display is now in the way of the architect's new goal, they can either alter the existing head-mounted display, if flexible, or simply replace it. This way, past imbrications of organizational routines and technology create an infrastructure that conditions future imbrications, as current and future technologies and organizational routines are dependent on and intertwined in each other.

4.2.2 How does technology influence organizational routines?

In the aforementioned section I sketched how imbrications can change organizational routines to produce new infrastructures. But when a technological affordance changes an organizational routine, what is then changed in that organizational routine? In the following section I will elaborate in more depth on how and what a technology changes in an organizational routine.

When a technology, like head-mounted displays, affords new ways of doing things it can create a change in an organizational routine (see step 1, Figure 9).

Importantly, this affordance is conditioned and made possible by the previous imbrication, imbrication 1. For example, the new affordance could have been prompted by a wish to reduce errors in the design process (set by one or more actors in imbrication 1, the human agency figure). This wish or goal then leads the actors to change the technology (the square shape) by for example adding a head-mounted display to the related hardware and software. This subsequently allows the actors to instantiate a new material agency instead or as a supplement to their current material agency identified in imbrication 1. In turn, the imbrication allows for an affordance to emerge. This affordance, and the technology that facilitates this affordance, can then potentially be enrolled and retained in the organizational routine.

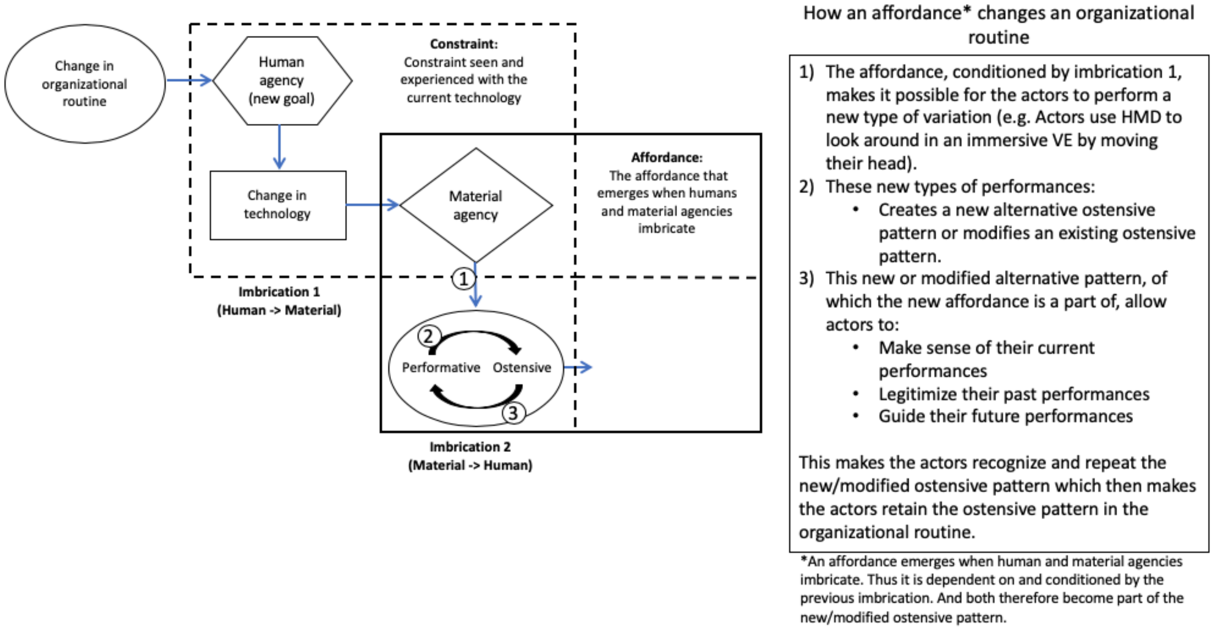


Figure 9: How an affordance changes an organizational routine.

The following step, step 2 in Figure 9, shows how a human (e.g. an architect) and a technology (e.g. a head-mounted display) and their agency can afford performances and be enrolled in the ostensive pattern of an organizational routine in the following two ways. First, by performing new affordances that have not previously been recognized as part of that organizational routine, the human and the material can together create a new ostensive pattern that supplements or replaces existing ostensive pattern(s). Second, a human, a technology and their agency can also choose to modify an existing ostensive pattern. This occurs when actors perform new types of variations that modify the existing actions of an ostensive pattern. This new or modified variation, made possible by the human, the technology, and their agency, can then become retained in the ostensive pattern of the organizational routine if this ostensive pattern can help the actors to make sense of their current performances, legitimize past performances, and/or help them guide future performances (see step 3 in Figure 9).

To elaborate further, new performances can be created when for instance an architect starts to use a head-mounted display because she has an intention to reduce errors when designing new buildings. This can for example be the case if the head-mounted display fulfills her intention by allowing her to look around in a natural manner, one of the criteria for immersion. Further, if other participants recognize the head-mounted display, and its affordance of looking around, the head-mounted display is retained in the ostensive pattern of the organizational design routine. And if successful enough, the head-mounted display might completely replace the existing performances and ostensive patterns of the organizational design routine. The architects and the head-mounted display, as well as the other technologies the head-mounted display is connected to, have then created a new organizational design routine because the existing ostensive pattern(s) have all been replaced by this new way of designing using a head-mounted display.

Furthermore, the affordance can also become part of an already existing ostensive pattern – which is the most likely scenario as it is uncommon not to use any parts or steps of an existing organizational routine. In these cases, the affordance of looking around using a head-mounted display is selected and retained in an existing ostensive pattern of for example an organizational design routine. The ostensive pattern, of which the architect and the head-mounted display are a part, is therefore likely to be one of more ostensive patterns of the organizational design routine. For example, it might be the case that the architects and engineers see the ostensive pattern, of which the head-mounted display is a part, as one of many alternative ways to design a house. If so, there might exist other ostensive patterns, of which the head-mounted display might not be a part, as it is normal for many different ostensive patterns to coexist. One such ostensive pattern could for example involve the use of only physical models and traditional monitors.

In either case, the affordance that is now part of an ostensive pattern, needs to be able to help the actors to make sense of their current performances, legitimize past performances, and/or help them to guide future performances. The following three examples illustrate how the actors should be able to use an ostensive pattern. First, actors should be able to use the ostensive pattern to make sense of their current performances. Following the aforementioned example, if architects and engineers start to use a head-mounted display, instead of a traditional monitor, with the intention to reduce errors when designing buildings, the affordance of looking around by moving one's head modifies their existing ostensive pattern of the organizational design routine, thus becoming part of it. In turn, if this new ostensive pattern helps them to make sense of their current performances by immersing them in 3D models of buildings and, as a result, identify more errors, the ostensive pattern might be maintained. Furthermore, if they can retrospectively make sense of and legitimize these actions, to themselves and others, the ostensive pattern might also be reused and thus maintained. And lastly, if they can prospectively see it as a relevant tool for identifying more errors in the future, this might also lead them to maintain the pattern.

If the ostensive pattern cannot help them to execute one or more of these "functions", the actors, in the organizational routine, might identify the affordance as a constraint and end up not repeating, not recognizing, and thus not maintaining the ostensive pattern. This can ultimately lead the actors of the organizational routine to not identifying the new/modified ostensive pattern as being part of the organizational routine. I will elaborate on this in the next section.

4.2.3 How a constraint leads to a new goal

Once a human and a material agency have fulfilled the goal set in imbrication 1 (see Figure 10), a technology can subsequently be perceived as a constraint.

That is, once a technology is enrolled in an organizational routine, it can be changed or un-enrolled if the actors see it as a constraint in one or more of the following ways. First, the affordance, shaped by a human and a material agency, can prevent actors from maintaining the pattern of which its affordance is a part (see step 1, Figure 10).

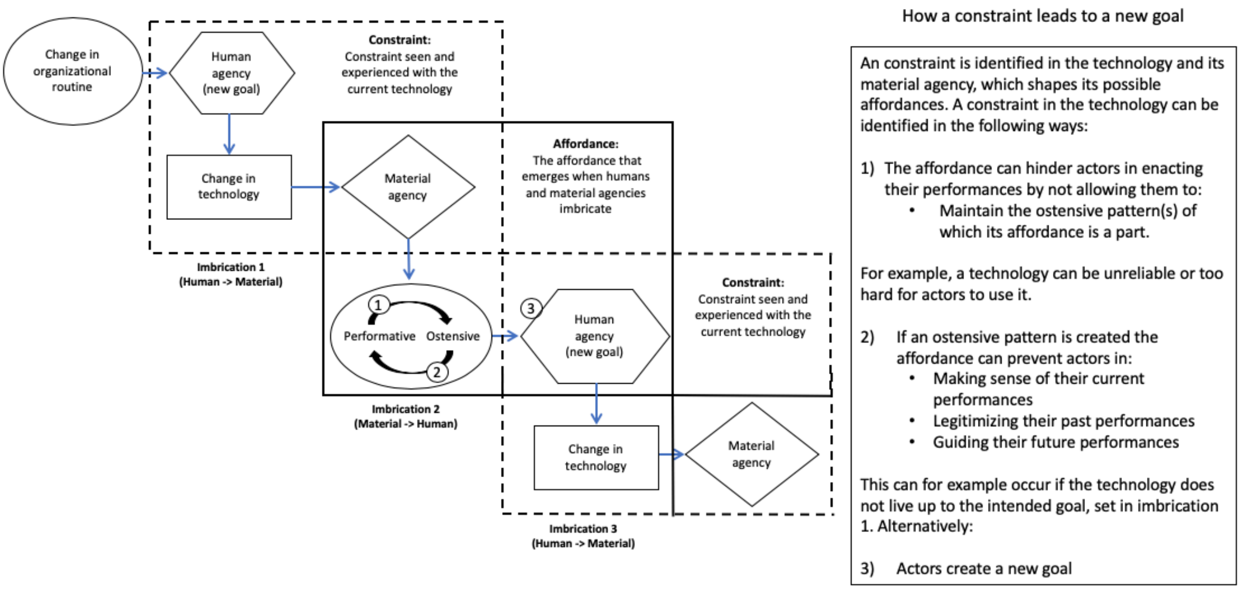


Figure 10: How a constraint occurs and leads to a new goal.

First, actors can identify a constraint in a technology if it does not help them to make sense of their current performances. They could for instance have experienced the head-mounted display as unpleasant to wear, which in turn makes them less inclined to use it and makes them maintain the ostensive pattern of which its affordance is a part. Ultimately, this can then result in them un-enrolling the head-mounted display because it constrains their current way of performing actions.

Another way that the technology can be seen as a constraint is if the actors cannot legitimize their past performances to themselves or to others. For instance, if an architect detects only a few design errors when looking around in the house during the organizational routine, and her colleagues in the organizational routine want a more effective way of identifying errors, the ostensive pattern of which the head-mounted display is a part will not be maintained and it can eventually be un-enrolled or modified. As a result, she and the other actors in the organizational routine are not able to legitimize the use of the head-mounted displays to themselves or to one another or others.

Lastly, the ostensive pattern of which the head-mounted display is a part can constrain actors and become irrelevant if it does not help actors to make sense of their future performances. For example, an architect might decide to see the head-mounted display as a constraint simply by being convinced by his colleagues' stories about the head-mounted display being uncomfortable to wear. Consequently, he might not be convinced that the ostensive pattern, of which the technology is a part, will be relevant to perform. This can in turn lead him to set a new goal that does not involve the technology or a modification of it.

To summarize, a technology constrains an organizational routine in one or more of the following ways. First, a technology can simply have issues which may lead the actors to not maintaining it by simply avoiding using its affordances in their performances. Second, actors can perceive a technology, and the ostensive pattern of which its affordances are a part, as constraining if the ostensive pattern, of which the head-mounted display is a part, cannot be used to make sense of actors' current actions. Third, if the ostensive pattern cannot be used to legitimize actors' performances retrospectively. And lastly, if the ostensive pattern cannot be used to make sense of their performances prospectively.

In the aforementioned sections I describe how a technology, its affordances and constrains relate to the performative and ostensive aspects of organizational routines. It is important to underline that the point of the two aforementioned sections was not to present an exhaustive list of how a technology affords or constrains organizational routines. Instead, it was to exemplify how a technology, and its emergent affordances and constraints, influences organizational routines, with the aim of showing how technologies sometimes come to matter in organizational routines and at other times do not.

4.2.4 How the imbrication lens helps to understand organizational routines and immersive technologies

The imbrication lens serves to underline the following important points.

First, while imbrications, and therefore organizational routines and technologies, are constituted by human and material agency, both are ontologically distinct phenomena. This distinction serves to highlight that these phenomena, and the agencies they both consist of, are different. In particular, as elaborated on in the philosophy of science chapter, while both humans and technology can do things, only people have the ability to form goals and only humans have the ability to form intentions (Emirbayer and Mische, 1998; Giddens, 1984; Pickering, 1995). However, while material agency is able to act on its own without human intervention, it does not have intentions of forming goals by itself (Pickering, 1995). Technologies can have an intention, but their intentions are formed and designed by humans as it is humans that have intentions and the ability to form goals (Leonardi, 2011; Taylor, 2016). Accordingly, it is always humans that, at some point, configure material agency and decide what goals are designed into technologies. But how technologies act and become imbricated cannot be determined beforehand. In fact, as many studies show, technologies can and will be used in many often unpredictable ways when they interact and intertwine with humans (Leonardi, 2011).

Relating this point to the review on organizational routines, in the section on "Digital and non-digital artifacts in the practice perspective on organizational routines", imbrication offers a language that builds on the current conceptualizations from organizational routines theory, which is primarily rooted in Actor-Network theory, with the aim of bringing forth the role of artifacts in organizational routines. In particular, by seeing both technologies and organizational routines as consisting of human and material agency, the imbrication lens matches with D'Adderio's (2011, 2008) argument to provide technologies with agency while avoiding technological determinism. But the imbrication lens differs in focus as imbrications explicitly argue that human and material agency are different and therefore should be seen as distinct phenomena. Accordingly, the imbrication lens maintains the distinction between the material and human agencies. Its emphasis is therefore slightly different than existing conceptualizations of technologies in organizational routines theory. That is, as existing literature utilizes concepts such as actants, it is difficult to trace if the actions are coming from humans or technologies. This way, human and material agency can become indistinguishable, such that action has no clear point of origin and either one of them can begin changes in sequences of action – the actions of human and technologies are, in the words of Actor-Network theory, hybrids (Latour, 1993; Leonardi, 2012, 2011). With the imbrication lens I aim at extending current literature on organizational routines, by arguing that while both the material and humans have agency, ultimately, humans decide how they respond and appropriate a technology (Leonardi, 2011). Therefore, humans and technology should be seen as ontologically distinct phenomena.

This clear distinction of human and technological performances further helps to make another point clear for the organizational routines and for literature on immersive technologies. In particular, it explicitly articulates that, while technology and organizational routines when imbricated both consist of human and material agency, the materiality of technologies needs to be considered in order to understand how agencies are weaved together to create or change organizational routines and technologies. Materiality here refers to the matter and form of technologies and helps to point out that what a technology is (its materiality), is important to distinguish from what a technology does (its material agency). Thus, the distinction between a technology and its material agency, what a technology is and what it does, sensitizes me, to a larger degree than prior literature on organizational routines and immersive technologies, to the materiality (matter and form) of technologies and therefore new technological developments of immersive technologies. This is done by introducing the theory of affordances (Gibson, 1977). Affordances directly conceptualize an object and its physical properties as they highlight an artifact's materiality and its possibilities for actions. However, the affordances of an artifact can change across different contexts even though its materiality does not. Thus, affordances are not exclusively capabilities of people or of artifacts – they emerge in relationships between people and the materiality of the things with which they come in contact (Hutchby, 2001). In short, the materiality exists independent of people and can remain the same across contexts and time, but affordances as well as artifact constraints do not. Consequently, people might see different affordances and constraints in a technology as they engage with artifacts and its materiality with distinctive goals. Affordances and constraints are therefore relational and as a result, actors' goals are shaped by the form and matter of artifacts and what they afford – and vice versa.

Second, the imbrication lens highlights, how past imbrications create infrastructure of technologies and organizational routines over time. This way, and to a larger degree than current literature on organizational routines, the imbrication lens sensitizes me to the surrounding context and how organizational routines and the materiality of technologies are embedded in organizational structures (Howard-Grenville and Rerup, 2016; Parmigiani and Howard-Grenville, 2011). In particular, when human and material agency imbricate, they generate an outcome by creating and/or changing organizational routines or technologies. An imbrication can in time become taken for granted, or black-boxed, by actors in an organization when technology allow actors to fulfil their goals and intentions. And when that happens, the new or changed organizational routine/technology becomes an infrastructure which conditions, but does not cause, future imbrications. For example, if a head-mounted displays become part of an organizational design routine and it fulfills the intention of the architects by helping them to reduce errors, it is likely to condition how future imbrications occur in the organizational design routine. For instance, the flexibility or inflexibility of the materiality of the head-mounted display, as well as the surrounding technical infrastructure it is connected to, will determine if it is changed or un-enrolled. If the materiality of the head-mounted display, and the technologies that it is connected to, is too inflexible, the same technology will constrain the new intentions and be replaced or altered. This way, past imbrications that have occurred will influence and condition the way that current and future agencies of organizational routines and technologies imbricate. In this manner, the implications of past imbrications are directly theorized and accounted for using a non-deterministic language, while also accounting for the materiality of the technology. Accordingly, the materiality of head-mounted displays and the other technologies that are involved in or connected to the head-mounted display can more easily be conceptualized as well. In turn, the imbrication lens helps to include the surrounding context that the organizational routine is imbedded in, in a more direct way than existing theory on organizational routines.

In summary, the imbrication lens helps to view the relationship between organizational routines and technology in a more dynamic way by regarding both technology and organizational routines as dynamic. It does so by keeping organizational routines and technology as ontological distinct entities as they are seen as different. Humans have the ability to form intentions while technologies do not, but technologies can have intentions designed into them. On the other hand, technology is different because it consists of a materiality that can potentially remain the same across time and place. Consequently, the imbrication lens helps to put focus on the materiality of head-mounted displays by keeping organizational routines and technology as distinct phenomena, in turn building on existing ways that organizational routines theory conceptualize artifacts. Technologies can change organizational routines by affording new performances, but technologies can also be un-enrolled or changed if they constrain the performances of actors in organizational routines. Furthermore, the imbrication lens aids in including the context and the embeddedness of organizational routines and technologies in a more direct way by directly conceptualizing the materiality of head-mounted displays and the other technologies that are connected to it, through the concept of infrastructure.

Hence, the imbrication lens complements existing theory of organizational routines by seeing both technology and organizational routines as potentially flexible. In turn, it makes it possible to better understand how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

Key concept(s)	**Definitions and explanations**
Imbrication	When a human's and a technology's agency tune in on each other, they eventually lock in on each other, and their agencies create an imbrication while remaining distinct entities. Imbrications either create or change routines, or at other times produce new technologies or alter them.
Infrastructure	Organizational routines and technologies are infrastructure. And the infrastructure is produced by the imbrications of the performances of humans and technologies – their agency.
Affordance	A technology's possibilities for actions which emerge in the relation between the performances of humans and technologies.
Constraint	The constraints a technology imposes on humans' goals which arise in the relation between the performances of humans and technology.

Table 8: Key concept(s) used in this section.

5 Method: data collection and analysis

In this chapter I present a description of the data collection and the subsequent data analysis. Both the collection and the analysis of the data consist of two phases, an initial, viz the explorative phase, and a subsequent, viz the longitudinal phase. In the section on data collection I initially describe the data collection for each of the two phases including a presentation of the empirical settings. Next, I describe the style of involvement during the collection of the observational data and lastly, I describe how I have gathered the three types of data, interviews, observations, and artifacts in the second phase of data collection. In the section on data analysis, I initially describe how the interviews were transcribed. Then I present how the data was analyzed, first in a general manner and then by presenting the specific methods for each of the two phases.

5.1 Data Collection: a data collection process in two phases

The data collection process for this thesis is divided into two phases. The first phase has predominantly been explorative by conducting interviews with five organizations in Northern Europe, mainly within the AEC industry. In the second phase of the data collection process I conducted a longitudinal study in an architect company. In all, this thesis data consists of 26 interviews, participatory observations over a 6 months' period, 4 to 5 times a week, and a host of documents, all of which will be presented in the following sections, starting with a description of the first exploratory data collection.

5.1.1 The first phase: an exploratory data collection[6]

The purpose of the first phase was first of all to find relevant organizations that were about to enroll or already had enrolled immersive technologies, like head-mounted displays and immersive VEs (produced by 3D CAD software), into their organizational routines, and to explore, through interviews, how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. Once I had found relevant organizations which fulfilled the above criteria, the main purpose was then to gain access to the organization in order to conduct a longitudinal investigation of how these immersive technologies influence organizational routines. However, before elaborating on the longitudinal study I initially present the explorative study.

The initial explorative study consists of five case descriptions of organizations, four of which within the AEC industry and one within the manufacturing industry. Common to the cases are the following factors. First, they have experience with enrolling head-mounted displays and immersive VEs, in their organizational routines but with varying degrees of success with regard to retaining them in the ostensive patterns of their organizational routines. Second, these immersive technologies were all enrolled in what I define as their organizational meeting routine. And lastly, while one of the four cases is within the manufacturing industry, the cases are all within graphic heavy industries where an essential part of their work is to design, produce, and communicate 3D artifacts internally to each other, during design and production, and externally to either potential or current clients.

The data collection process started in August and ended in December of 2017. All of the five organizations are located in Northern Europe where some of the major ones also provide services in other regions as well (see Table 9 for an overview). The chosen organizations were all currently using head-mounted displays to show the immersive VEs in their organizational routines. For each of the interviews an interview guide was created to keep focus on the head-mounted displays

6 This chapter is an extension of: Hofma, C.C., Constantiou, I., 2018. Immersive virtual environments: understanding its influence on organizational routines, in: The 26th European Conference on Information Systems (ECIS) 2018. Association for Information Systems. AIS Electronic Library (AISeL).

primarily and their use in organizational routines (see appendix: Interview guide – The first explorative phase). However, due to the explorative nature of the interviews, the interview guides acted mostly as a way to keep track of facts of the organization but also to make sure that the topic remained relevant for the research question and did not steer too much in an irrelevant direction. For example, the interviewees often mentioned augmented reality during these interviews because this technology is often associated with head-mounted displays. In addition, a small project description of this thesis was also sent to the interviewees before the actual interview took place. And during each of the interviews I took notes while also recording the interview. During all of the interviews, except the interview with General Contractor B, a head-mounted display was present that served to demonstrate how the employees were using it in practice.

The first organization is a comparatively large architect company in Northern Europe. As an architect company (Architect Company A), it is involved in the planning and/or the design phase of construction projects (see Figure 11). I contacted this organization because they had used head-mounted displays since 2015, with the main intent of improving communication with existing and current clients. Traditionally, they had used paper and pen, 2D CAD drawings, and a traditional monitor to show potential clients building designs, but since 2015 they had complemented these tools with head-mounted displays.

The interview with the architect company was conducted in the beginning of August 2017 and lasted 46 minutes. The interview was semi-structured as an interview guide was used, but to keep the explorative nature of the interview, I mainly asked open-ended questions. These questions related primarily to organizaitonal routines as well as immersive technologies in general, in particular head-mounted displays as well as the surrounding technical infrastructure it is connected to. The interviewee was the senior architect in charge of their use of head-mounted displays. As it was the first interview, the interviewee was asked to do most of the talking unless going off into more irrelevant topics such as for example augmented reality.

The second organization is a comparatively large general contractor (General Contractor A) in Northern Europe. It covers all the phases of a construction project, from planning over design to execution of any given project (see Figure 11). Since 2010 they have been sketching and designing building models through the use of various CAD software. But from 2014 onwards, they have tried to incorporate more immersive technologies, such as head-mounted displays, into their organizational meeting routine.

The interview with the general contractor was conducted in mid-August 2017 and lasted 1 hour and 10 minutes. During the interview, two employees were present: a general manager with experience in using head-mounted displays and an engineer that developed 3D models for use in head-mounted displays. The interviewees initially introduced themselves and were subsequently asked to talk about if they used head-mounted displays and if so, how and in which organizational routines they used them.

As this second interview progressed, some similarities emerged which I asked the interviewees to elaborate and provide examples for. It became clear, for example, that they were mainly using head-mounted displays during their organizational meeting routine.

The third interview was with a medium-sized general contractor in Northern Europe (General Contractor B). They provide services in all the different stages of construction projects (see Figure 11). Since 2012, they have been using VEs in the form of CAD software to sketch and design 3D models of buildings for demonstrations to their clients. Traditionally, 3D models were displayed on regular computer screens but since 2015, they have been using head-mounted displays to give clients a more immersive experience.

I conducted the interview in mid-August 2017, and it lasted for 48 minutes. Four 4 employees were present: two project managers that had experience with technologies and two employees that were responsible for the technical development of head-mounted displays and immersive VEs. As with the aforementioned interviews, I predominantly asked open-ended questions relating to how they used head-mounted displays, as well as the surrounding technical infrastructure it is connected to, both internally between colleagues and externally together with clients. However, due to the presence of four employees, dialogue and discussion often arose between the interviewees. Most of the time, the interviewees contributed roughly equally to the dialogue. As a consequence, during the interview, I informally took on the role as a moderator by asking elaborating questions when, for example, their dialogue came to an end or if they steered in an unwanted direction which for example did not have to do with head-mounted displays or with the immersive VEs they facilitate. In this manner, I sought to maintain the explorative nature of the interviews while also building on the knowledge I had already gained from the previous interviews.

The fourth organization in this first exploratory phase is a small product development company that develop ideas into products and subsequently markets and sells them for other companies. To build these products, they utilize various forms of 3D CAD software. But since 2014, they have used head-mounted displays to sell virtual prototypes of future products to their clients to make the sales routine more convincing.

The interview with the product development company was done at the end of August 2017. The interview lasted 1 hour and 30 minutes, and the interviewee was the CEO of the company. As with the aforementioned interviews, I had prepared an interview guide although slightly modified to also ask about some of the themes that the previous interviewees had experienced. However, these questions were usually not necessary, as the interviewee in this and the previous cases often mentioned some of the same themes. For example, as with the previous three interviews, this organizaiton also used head-mounted displays when interacting with clients during their organizational meeting routine.

I conducted a last interview in this exploratory phase with a large architect company (Architect Company B). They mainly provide services in either the planning and/or the design phase of any given construction project (see Figure 11). This architect company initially started to experiment with head-mounted displays in 2015 but it was not before 2017 that they had started to use it to communicate drawings to clients during their organizational meeting routine.

The interview was done in the beginning of December 2017 and had a duration of 1 hour and 7 minutes. The interview was semi-structured as an interview guide was used. But to keep the explorative nature of the interview, I mainly asked open-ended questions. These questions related primarily to the organizational routines in which they had used head-mounted displays while also touching upon how it was used together with e.g. the CAD software they were using. During the interview, four employees were present, all of whom were architects by trade while also being involved in the implementation and use of the head-mounted display. This cast me as the interviewer as predominantly a moderator of the interviewees' dialogue and discussion which entailed that I asked elaborating questions when their dialogue came to an end or if they steered in an unwanted direction which for example did not have to do with head-mounted displays, immersive VEs or other related hardware or software.

Organizations	**Date**	**Duration**	**Number of interviewees**
Architect Company A	Beginning of August 2017	46 minutes	1
General Contractor A	Middle of August 2017	1 hour 10 minutes	2

General Contractor B	End of August 2017	48 minutes	4
Product Development Company	End of August 2017	1 hour 30 minutes	1
Architect Company B	Beginning of December 2017	1 hour 7 minutes	4

Table 9: Overview of phase 1 interviews.

The data collection of this initial explorative phase ended when I gained entrance to a sixth case organization in mid-December of 2017, also an architect company situated in Northern Europe. This initiated the second phase of the data collection process where I gathered more elaborate and in-depth data. To better understand the context in which this second phase of data collection took place, I will in the following section initially describe the case before elaborating on how the data was collected in that architect office.

5.1.2 The second phase: an architect office in Northern Europe

The data was collected in an architect office in Northern Europe. Established in 2008, it is a fairly new company with around 23 employees, all sitting in an open office, and of whom 18 are employed on a permanent basis while the remaining five are interns who are typically replaced every 6 to 12 months. All employees were under the age of 40 at the time of this investigation. Many of them were open to trying new technologies, like head-mounted displays or new plug-ins that could produce immersive VEs, and often viewed themselves as being front runners in an otherwise rather traditional industry which is less digitalized compared to many other industries in Europe (EU BIM Task Group, 2017). They worked on about 5 projects at the time, ranging from the restoration of sports centers to the design of new churches.

The architect office in which the data was collected used a three-phase and eight-stage process model to illustrate the ideal progress of any given building project (Figure 11).

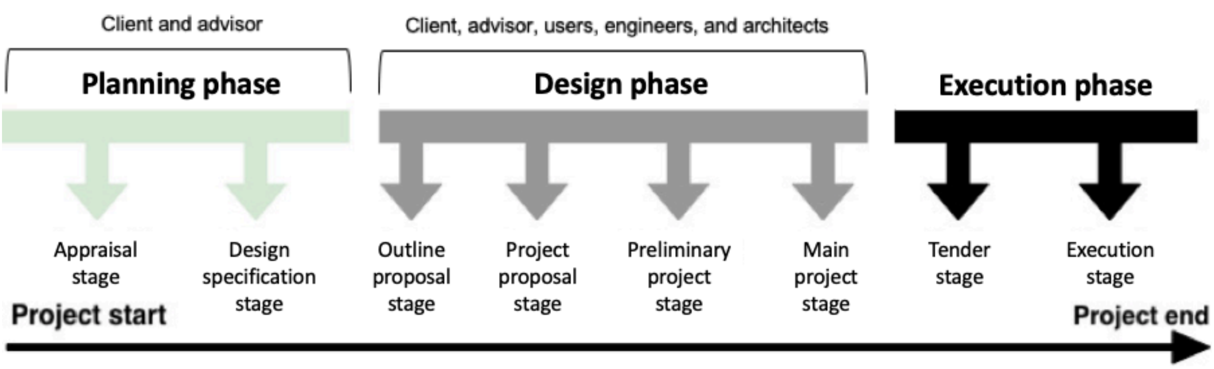


Figure 11: Overview of the architectural design process.

To understand the research setting, I will elaborate on the first two phases and their respective stages, the planning and the design phase, due to the prevalence of head-mounted displays in these parts of the building projects.

The first phase, planning, consists of two stages: an appraisal and a design specification stage. During the first stage, the client makes an appraisal. The client makes an appraisal during the first stage where a document is drafted that describes in words the conditions relevant to the project. In addition, the document specifies the client's requirements and vision. The requirements are typically written in words and accompanied by pictures for reference. No new architectural drawings are made in this phase. In addition, only the client and her advisors are present in this stage.

At the design specification stage, a competition brief is made by the client in a collaboration with professional advisors, if any, typically an engineer and/or an architect. In this brief, the appraisal is described in more detail by stating the purpose of the building, size of the rooms, functions of the room, the budget, and time frame, and by providing other relevant details. No new architectural drawings are made in this stage. However, architectural drawings, like site plans, elevation plans, and the like, of any existing buildings or facilities involved in the project are included. Once the brief has been completed, it is then used to invite one or more companies, e.g., the architect offices or a general contractor. Alternatively, a call for a proposal is held. In both cases, the brief plays a key role, as the companies should create a proposal that satisfies the client's requirements stated in the brief. These proposals typically include a range of 2D artifacts, such as site plans, elevation drawings, floor plans, and the like. In addition, reference pictures as well as screenshots of 3D virtual models are included in the proposals and presented to the client so he/she can decide which plan best interprets his/her vision. In this stage, an architect office is chosen to design the project.

Once the client has chosen a submitted proposal, the next phase, which is the design phase, starts with the outline proposal stage. The outline proposal is typically developed based on the winning proposal and in dialogue with the client. Specifically, the project is described in more detail by creating a (revised) budget, a specific time plan, a more detailed architectural concept, a thorough description of functions, and a comprehensive description of materials, among other things. At this stage, new architectural drawings of a site plan showing the relative location of the buildings (scale: 1:500/1:1000), floor plans and elevation drawings (scale: 1:200/1:500), among other things, are produced by the chosen architect office together with the client and potential future users. In addition, the virtual model(s) are created by the architect office.

At the project proposal stage, the outline proposal is revised to include final decisions that are pivotal to the project. The existing architectural drawings are revised to include new suggestions from the client and/or users. In addition, technical drawings are made in collaboration with engineers, e.g., 2D drawings of the plumbing systems, for example. Virtual models are updated with any new information as well.

At the preliminary stage, the project proposal is revised to such an extent that it can form the basis for approval by the authorities. During this phase, architects and engineers provide more in-depth descriptions and calculations of choice of materials, the architecture, zoning, energy consumption, fire safety, and other things. They also design in more detail the 2D architectural drawings (floor plans, section plans, elevation plans, site plans, etc.) and technical drawings that adhere to the requirements of the authorities. Virtual models are updated with any new information as well.

In the last stage of the design phase, the project is described with such a level of detail that it can form the basis for final clarification of the conditions contained in the planning permission, as well as for tendering, contracting, and construction. Thus, many of the aforementioned documents need to be more detailed and new ones created. Therefore, the data collected depends on when the architect office starts to be involved in a project. This usually happens when they send in a competition proposal, at the end of the planning phase. In the following sections, I elaborate on the data collection and analyses.

5.1.3 Style of involvement in the architect office

The field work was conducted over a 6 months' period with the overall goal of reaching a better understanding of how head-mounted displays, primarily, influence the employees as they conducted their daily tasks. This was possible because I was assigned the role as a full-time intern. This meant that I got unrestricted access to their office by getting a key card, an e-mail, and full access to servers and internal meetings. In addition, I also got my own office desk. I therefore tried to act like a "formal" employee by showing up at the office during normal work hours 4 to 5 times a week, 5-8 hours a day. In this manner, I participated in formal matters like their daily and weekly meetings, but I also attended informal meetings, lunches, and even a couple of social events. This meant that I became an active part of their daily work, sometimes helping out with practical matters, such as their weekly cleaning routine, while also talking to the other employees about my research if they were curious in some way or another.

My involvement in the organization reflects the spectrum of engagement with the field that Walsham (2006) has identified. At the one end of the spectrum, the highly involved researcher can be placed – or the participatory observer. While at the other end of the spectrum, Walsham places the outside or "neutral" observer. The neutral observer is importantly not an unbiased observer as: *"We are all biased by our own background, knowledge and prejudice to see things in certain ways and not others"* (Walsham, 2006, p. 321). During the six months that I was doing observations, my role as an intern and observer fluctuated between the two ends of the spectrum, but it was primarily at the neutral-observer-end of the spectrum due to my limited professional experience as an architect or engineer. As a neutral observer, my intent was for example not to align myself with any particular group (e.g. architects, engineers, building constructors) or any given individual. However, that being said, I was provided with a mentor, an architect who helped me to get settled initially with the practical aspects such as being assigned a particular office desk but also helped me to get acquainted with the other employees in the organization. To my knowledge, though, this was normal practice when other new interns are starting in the organization, for example architect interns. In an effort to maintain my role as an outsider, I often introduced myself as a Ph.D. student while also revealing my intent and purpose of being there: to observe and ask how they worked with head-mounted displays – and related immersive technologies. In addition to my mentor, I also tried to get especially acquainted with the people that were relevant to my research. This was initially the employee, an architect, who had taken the initiative to acquire the head-mounted display to begin with. But I quickly realized that I should focus on not only that particular architect. Instead, I shifted my attention to anyone that had previously used, were currently using, or planned to use head-mounted displays in any of the office's ongoing projects that they were participating in. As a result, I tried not to align myself too much with any particular person or group for a long period of time.

As time progressed, I started to become a more integrated part of their daily work by for example helping them with practical matters and participating in social events, in order to step out of the role of being "the research intern" only. I tried, for example, to contribute by helping out with smaller technical issues using my technical knowledge that I had acquired through my educational background as a computer scientist, but also by using my experience as a researcher, providing feedback to one of the architects who was writing an application for an industrial Ph.D.

scholarship. Lastly, I also disseminated the knowledge and insights I acquired to the employees by contributing to the planning and content of an industrial network meeting on the use of virtual reality in the AEC industry. But also, through informal day-to-day talks over for example lunch. In this manner and as time progressed, I started to participate more in the daily work performances of the employees and thus also became part of and shaped their organizational routines in these direct interactions with the actors, but also indirectly by simply being present and wanting to observe how they used the head-mounted display and other related hardware and software. For example, while I was sitting next to one of the architects, he asked me to help him decide on what texture he should assign to a door he was modelling. In this direct but also in many other indirect ways, my presence naturally influenced the employees performances, their interactions with head-mounted displays and hence how this technology influence their organizational routines. But on the other hand, by engaging in their daily work I got a more in-depth understanding of how they worked with head-mounted displays and how it influenced their performances. This included getting more nuanced insights into for example potential issues with the head-mounted display, as well as other immersive technologies like the immersive VE that it displayed, that coincidentally arose during their daily work with. But more importantly, because I was seen as an intern and participated in some aspects of their daily organizational routines, I established a more trustful relationship with the employees, which allowed me to gain a better understanding of their problems, which in turn helped me to get a more in-depth access into their issues that would otherwise not be possible through e.g. interviews or by taking on the role of a less involved observer (Walsham, 2006).

As the field work came to an end, in late June 2018, I slowly started to be less involved and again became more of an outsider as I started participating less regularly in their daily activities. And in addition, because the latter parts of my field work ended in June, up to the summer holiday, less activity occurred at the office because people started to go on vacation. Consequently, there were less events and tasks I could participate in and as my field work came to an end, I naturally fell into the role of an outside observer.

My role thus fluctuated from starting out as an outside observer to slowly becoming a more involved observer, and then at the end I became an outside observer again.

5.1.4 Collection of data: interviews, field notes, and artifacts

The data collected during the field work encompass 19 interviews with 12 architects and one engineer, and some of the architects as well as the engineer were interviewed twice. This resulted in 200 pages of transcripts. Further, during the 6 months of observations data was collected on a daily basis by writing down notes during the days where I was in the field which was typically 4 to 5 days a week, 4 to 8 hours a day. And lastly, during my field work I identified many relevant files and documents, such as presentation slides, meeting minutes, vivid still 2D and 3D renderings, and 2D and 3D artifacts like interactive 3D models of various projects. All in all, I collected more than a hundred relevant files going back to 2013. The process of collecting these data as well as the reasoning behind it will be elaborated on in the following sections.

Initially, I sought to identify relevant organizational routines in which the head-mounted displays were enrolled. From an initial interview done in November of 2017 with one of the partner architects, as well as from the first phase of data collection, I recognized that they had mainly been using head-mounted displays in what I identified as the organizational meeting routine. Further, I also collected archival data, such as competition briefs, typically used in the competition and planning phase of projects to convince a jury or potential client of a project that they had used head-mounted displays in at least five different projects. The head-mounted displays having been used in these projects was later confirmed by my observations and informal interviews with the people involved in these five respective projects. Based on these field data, I could then start to perform a preliminary analysis of the data to identify the ostensive patterns of the organizational meeting routine (Pentland and Feldman, 2008b). With this organizational routine in mind, I created an interview guide which primarily helped me as an interviewer to understand the facts of each of the four projects. The interview guide further had some guiding questions which related to the interviewee's role and main tasks in the project, the technologies they used, and lastly specific questions relating to the head-mounted displays (See appendix: Interview guides – The second longitudinal phase). I then set up three interviews with four architects (see Table 10). The interviews were centered around the projects that the architects were part of or had been involved in and in which they had used a head-mounted display. With the interviews, I aimed to follow a bottom-up approach. This meant that I invited the interviewees to primarily focus on concrete examples of narrative fragments that describe actual instances of their performances in these organizational client meeting routines (Pentland and Liu, 2017). I did this by asking them to mainly talk about one specific project, or if they came up with more general descriptions, ostensive patterns, I asked them subsequently to provide descriptions of performances that could exemplify these ostensive patterns. I did this to facilitate a more explorative interview approach. Because of this, the following two things became clear during the interviews, but also after the interviews had been conducted.

First, while they initially had intended to use the head-mounted displays in the organizational meeting routine, they were closely connected to their internal tasks which comprised e.g. preparing the materials that were used during client meetings. I later conceptualized these tasks that were not performed within the organizational meeting routine itself, as their organizational design routine. Hence, two organizational routines were then identified through interviews and daily observations.

Second, during the interviews the employees often mentioned and emphasized the importance of the surrounding infrastructure and how it helped to create a more immersive VE - the related hardware and software. For example, during the interview they often mentioned a plug-in that produces a vivid immersive VE by rendering the models on the fly. This immersive technology, the plug-in, was mainly acquired with the intention of making their current 3D CAD programs compatible with the head-mounted display, but during later observations and interviews it proved to be just as important as the head-mounted display itself as they often used it to test their designs in a quicker and more immersive way than was possible before. In fact, they often used it without the head-mounted display by showing and walking through the model while looking at a traditional PC monitor. After these initial interviews I therefore started focusing on not only the head-mounted displays but also the surrounding infrastructure, including the plug-in, software, and hardware that facilitated the immersive VE. In short, the related hardware and software.

Date	**Organizational routine**	**Duration**	**Number of interviewees**
30.11.2017	Both	38 minutes 18 seconds	1
25.01.2018	Client meeting	34 minutes 2 seconds	2
26.01.2018	Client meeting	17 minutes 7 seconds	1
29.01.2018	Client meeting	40 minutes 9 seconds	1
13.03.2018	Client meeting	1 hour 24 minutes 3 seconds	1
20.03.2018	Client meeting	42 minutes 21 seconds	1
27.03.2018	Client meeting	60 minutes 13 seconds	1

04.04.2018	Client meeting	48 minutes 21 seconds	1
05.04.2018	Client meeting	1 hour 24 minutes 3 seconds	1
03.05.2018	Client meeting	43 minutes 31 seconds	1
16.05.2018	Designing artifact(s)	55 minutes 29 seconds	1
16.05.2018	Designing artifact(s)	1 hour	1
23.05.2018	Designing artifact(s)	59 minutes 49 seconds	1
25.05.2018	Designing artifact(s)	52 minutes 16 seconds	1
13.06.2018	Designing artifact(s)	54 minutes 47 seconds	1
14.06.2018	Designing artifact(s)	1 hour 13 minutes 57 seconds	1
21.06.2018	Designing artifact(s)	1 hour 9 minutes 26 seconds	1
21.06.2018	Designing artifact(s)	59 minutes 50 seconds	1
22.06.2018	Designing artifact(s)	47 minutes 54 seconds	1

Table 10: Overview of phase 2 interviews.

After conducting the first interviews, I planned to get more in-depth knowledge on these two organizational routines, the head-mounted display and the surrounding infrastructure used in them. However, the main goal with the interviews was primarily to get information on the first organizational routine, namely the organizational meeting routine. For this I planned and conducted eight semi-structured interviews. These interviews were done with seven different persons. These interviewees had all been working on projects that again used or planned to use head-mounted displays in their respective projects (see Table 10 for overview of interviews). The interviews were primarily done with architects and the one engineer that were employed with the company. The interviews were done differently from the first round of interviews as the primary goal was now to a get a top-down perspective on the identified organizational routines. Contrary to the first interviews, the goal of doing a top-down investigation of any given organizational routine is to primarily, but not only, identify the ostensive aspects of an organizational routine. And because the ostensive patterns are generalizations of organizational routines, the interviews automatically started to be more structured and less explorative. This is done by interviewing a knowledgeable informant(s) who then:

> *"…is asked to generalize about a focal routine. Thus, the data can be interpreted as an ostensive aspect of the routine from the point of view of that informant"* (Pentland and Liu, 2017, p. 5).

This top-down view on the organizational meeting routine was facilitated, in part, by using a modified interview guide originally created to conduct a top-down interview by Pentland and Liu (2017, p. 5) (see appendix: The longitudinal interview guide (focus on the ostensive)). The interview guide originally aimed at elaborating on different aspects of the ostensive pattern of the organizational meeting routine. However, I modified and used it to shed light on both aspects of the organizational routine as well as the immersive technologies by asking for particular examples when we talked about the ostensive patterns. In particular, with the interview guide I sought to establish the following factors.

First the boundaries of the organizational routine in a way that makes sense to both the informants and the researchers.

Second, I asked the interviewees to provide a general description of the organizational meeting routine e.g. what is the purpose of the organizational routine.

Third, the interviewees were asked to break the general description into individual steps. In a fourth step, I then asked the informants to identify the sequence of steps: what happened first, what happened next, and what happened last in the organizational routine. But also, if this sequence was the normal way for that organizational routine to be performed or if there were any alternative sequences.

Lastly, the informants were asked to estimate the frequency of these alternatives to understand the importance and prevalence of these alternative sequences (Pentland and Liu, 2017). The above questions were asked to establish a common understanding of the organizational meeting routine and were largely identical to the interview guide template put forth by Pentland and Liu (2017, p. 5). In particular, these questions were mainly aimed at asking into the ostensive aspects of the organizational routine. Or the typical instances of the organizational meeting routine. However, to counterweigh these questions aimed at the ostensive aspect, I often asked the informants to supplement their answers with examples of organizational routines – that is, actual instances. By doing this, the ostensive patterns as well as the performative actions were identified (Pentland and Liu, 2017). In the last part of the interview, I directly asked questions relating to head-mounted displays, e.g. at what point in the process/sequence was the head-mounted display introduced? When was it introduced into the process? If the interviewee could provide some good and bad examples of how they had used head-mounted displays in the organizational routine? And lastly, I asked if the head-mounted display changed how you would normally work with the clients or users? The above questions were the intended sequence of questions. However, during the interviews, questions could often be skipped in case the interviewee had already answered any of the questions. For example, because I started out with presenting the purpose of the interview, and because they also had an idea of it as I informed them about the purpose of the interview beforehand, they often related my questions to head-mounted displays throughout the interview e.g. by providing examples. This means that, the interview guide only served as a guide to facilitate these semi-structured interviews. In addition, while I strived to focus on mainly one of the organizational routines identified, during the interviews they would often also mention or refer to tasks that had to do with the organizational design routine.

The remaining five interviews were done by sitting next to the employee while the architect or engineer was working on their computer and explaining what he/she was doing. While doing so, questions were asked that were related to his/her task at hand. These interviews focused primarily on the organizational design routine. The aim with these interviews was three-fold.

First, with these types of interviews I sought to get further insights into the actual performances and supplement the performative accounts given during the previous phases of interviews because during those interviews, the interviewees not only referred to tasks done in the organizational meeting routine but also to tasks that I conceptualized as part of the organizational design routine.

Second, these types of interviews helped to focus attention towards not only the human but also the technology.

Third, by including the technology actively in the interview, they could show me how they performed the organizational design routine with the head-mounted display, the surrounding infrastructure and other immersive technologies (e.g. the plug-in), instead of explaining how they used it. In turn, this provided me with a more detailed account of how they used the head-mounted display in this organizational routine. During these interviews I used a similar interview guide as I had done in the previous instances, which helped to establish e.g. the overall ostensive pattern of the organizational design routine, the ostensive aspect. However, because the primary focus was on the performative parts of the organizational design routine, these questions were not used to the same extent. In particular, questions were only asked that related to the three parts of the aforementioned interview guide.

To reiterate, the first part helped to establish first the boundaries of the organizational routine in a way that makes sense to both the informants and the researchers. In the second part, the informant was asked to provide a general description of the organizational routine and its purpose. The last part related to the use of the immersive VEs and head-mounted displays in this organizational routine. In this manner, both the ostensive pattern and the performances of the employees were sought to be captured.

During all three phases of interviews, the informants were recorded. In addition, I, the interviewer, kept a printed copy of the interview guides in front of me and a notepad for notetaking purposes. Before starting the interviews, I asked the informants if I could record them while stressing at the start of the interviews that for ethical reasons, everything recorded and noted would be kept strictly confidential, but also to make the interviewees comfortable and potentially more truthful (Walsham, 2006).

5.1.4.1 Observations and field notes

The participatory observations helped to elaborate on what the actors did and what they said when doing their organizational routines, which is crucial when wanting to understand the performative actions and ostensive patterns of the actors involved in the different organizational routines.

Specifically, by participating, observing, or by conducting informal interviews, I got an invaluable opportunity to verify, elaborate, or reconfigure my understanding of the organizational routines described during the formal interviews (Pentland and Feldman, 2008b). My observations were noted on my computer at the desk that was allocated to me. When sitting or walking around in the office, however, I only took mental notes which I wrote down as quickly as possible when coming back to my desk. I consciously avoided walking around with for example a notepad to note down any points as: *"stopping to write down something the person has said may be the quickest way of ending that conversation."* (Neyland, 2008, p. 104).

However, as the employees were sitting in an open office, I could, from my desk, hear and observe many of the conversations and interactions – both between the employees themselves, but also when they were meeting with clients and future users as these meetings were held in areas of the office that were not cut off physically from the rest of the office. At other times, they were meeting clients in two designated meeting rooms. And while it was not possible to hear what they were saying during meetings I did not attend, I could often see what they were doing during meetings as there were transparent glass walls and doors between the office and the meeting space. The notes I made were organized in a diary format, a common way of writing down and organizing field notes (Neyland, 2008) (see Figure 12, for example). In all, around 100 pages of field notes were captured in this manner.

Friday 04/05 (ODR)

Friday, 4 May 2018 10.08

Time and Date: - If written after observation, date not noted or page created before/after observation	Friday, 4 May 2018, 10.08
What is being observed? - Project, - Routine, - Activity	Project: [redacted] Routine: Organizational design routine
Descriptive information - Who, what, when, where, why, how - Specific facts: numbers, details etc. ? - Sensory impressions? - Insider language?	**Who,** [redacted] **what,** Talking with a collaborator over the phone - a builder **when,** during the morning **where,** At the office **why,** There was something about aligning expectations of how furbished the interior of some new houses should be. **How** [redacted] was talking on a phone with a collaborator - I'm pretty sure it was either a builder, an electrician, or an engineer. While she was talking with the collaborator, she was walking back and forth between her computer and a big "poster" with prints from the project. When at the poster, she was drawing on a 2D plan printout which was attached to the big poster. She has often done this. When she was at her computer, she was looking at a another, "virtual", 2D rendering of the same plan drawing for the same project.
Reflective information - Reflection on the day's experience - How did I impact the situation?	
Emerging Questions/Analysis - Potential lines of insights, - Useful theories? - Further investigations?	This goes to show the importance of being flexible. Not only are they talking on a phone with collaborators, they are also looking at printouts all the time. This is just an example. This couldn't be done if she was wearing something that was physically constraining her eyesight
Document, File etc. - Something that documents what you observed	

Figure 12: An example of field notes written in a diary format.

This means first of all noting the time and date of the observation, which was done automatically by the word-processing program that I used for this task. I also noted the context of each of the observations to provide a more nuanced account of the specific situations in which for example the doings occurred, while also trying to include the involved human and technological actors. To encompass and remember to account for these particular details, I utilized a template for every observation that I wrote down (see appendix: Template). This template was structured so that I had to answer the following questions when writing down the observations: what was being observed (what organizational routine, activity, project, or task), who was being observed, when was this happening (at what time of the day, the duration of the activity, task etc.), where was it happening (e.g. in the meeting room or at one of the desks), why was it happening (e.g. why did a colleague go over to another colleague to talk about something), and lastly how it was happening. In addition to these descriptive questions, there were two other categories. The first one related to any reflections that I had for that particular observation (e.g. if I wondered why that action happened), while the second one was for emerging questions that were potentially prompted by the observation (e.g. theoretical insights). Through the descriptive questions, I sought to not only note down the observation itself but also to provide it with a context in order to specify a more nuanced description of any given observation. With the categories on reflective and emerging questions, I aimed at keeping the more descriptive parts of the observations separate from any potential reflections or potential theoretical insights that might be prompted by the observations. This latter point was not with the intention to provide a "neutral" or "unbiased" observation which I argue is not possible. Instead, I did this so that, at a later point, I would be able to apply other insights to the observations, e.g. a new theoretical insight, after the field work was done.

With this in mind I tried to acquire rich data and an in-depth understanding of the context from which the data originated. These observations were collected on a daily basis while being in the organization. This was typically 4 to 5 times a week, 4 to 8 hours each day. The field notes were normally written down while I was at the office and if necessary, I extended them once out of the research setting as: *"…times outside the field can be important for writing up observations and attempting some form of organization of observations"* (Neyland, 2008, p. 81).

Lastly, during the six months in the organization I also collected relevant files like: presentations, competition proposals, meeting minutes, renderings, and 2D and 3D artifacts (e.g. files) such as virtual environments. The artifacts were an important type of data in the following ways. First, they could help me to elaborate, confirm, or disconfirm current assumptions and hypotheses during data collection. More importantly, the artifacts helped me during analysis to confirm or disconfirm these hypotheses or assumptions put forth by myself or/and the interviewees by comparing e.g. meeting minutes with interview transcripts. Second, by reading and finding relevant documents to the two organizational routines I was investigating, I could see traces of when and how head-mounted displays, and other immersive technologies, were used to communicate certain aspects of a project as the technologies left behind certain types of files. In this manner, I could use the artifacts also during interviews to prompt a dialogue about how the interviewees had used the head-mounted displays previously in any given project going back to 2013. Lastly, the artifacts were used to better understand the ostensive patterns of the investigated organizational routines. By analyzing and comparing for example meeting minutes, Gantt charts, and process models, I could deduce and ask the employees about the specific tasks in any given meeting and compare them to the documents to either confirm, disconfirm, or elaborate on them.

Together, the formal and informal interviews, observations, and artifacts all contributed to a more robust analysis as the three types of data sources could complement each other in the aforementioned ways and thus help to derive a sounder analysis. In the following section, I will outline how I conducted the analysis.

5.2 Data analysis

I will now present the data analysis of the thesis and how it relates to the research question, initially describing how the interviews were transcribed, and how the observations and documents were prepared for the analysis. Once these initial steps have been presented, I will outline the general approach that I utilized for both the analysis and the first and second phase. I conclude this section by describing in detail, for each of the two phases, how the data was coded.

5.2.1 Transcription and preparation of data

In all, I performed 24 interviews across the two data collection phases. As mentioned, all of the interviews, except one due to technical issues at the time of the interview, were recorded on audio files. I, the author, chose to record the interviews as it could help to revisit, in more detail, what was being said during the interviews (Walsham, 2006, 1995). However, recording the interviews will of course change the relationship between the interviewer and the interviewee(s), in the sense that some sensitive issues might be skipped by the interviewee (Walsham, 2006, 1995). If the interviewees did not mind that the interview was being recorded on audio, I tried to mitigate this potential pitfall by stressing, at the start of every interview, that everything would be kept confidential and anonymized. However, during some of the interviews, there were sometimes indications of the interviewees being cautious of what they were about to say as they stressed that what they were about to say was confidential. Therefore, it cannot be denied that some important details might have eluded me, but I initially decided that the benefits outweighed the aforementioned risks.

The transcriptions of the interviews were partly done by the author and partly by a professional transcriber. The five interviews from the first exploratory phase were transcribed by the author. The 19 interviews were transcribed by the professional transcriber with the aim of increasing the efficiency of the transcribing process.

When transcribing the interviews I collected in the first exploratory phase, focus was being put on passages that were relevant to the research question while less relevant passages were summarized (Kvale, 2007). For example, the interviewees also mentioned other technologies like augmented reality as they are often seen as a different technological variation of head-mounted displays and immersive VEs. However, this thesis does not deal with technology passages like these, and other irrelevant technologies were only summarized or noted with a time stamp indicating the length of the passage in question. The passages relevant to the research question were transcribed word for word, excluding repetitions and intonations etc., however, unless these aspects had an impact on the meaning of what was said, like when interviewees emphasized a point by for example repeating a sentence. Relevant passages were qualified primarily by their relevance to the research question. If the interviewees for example talked about what they did during meetings with clients and provided examples, I considered it relevant as it related to their performances of the organizational routine. Alternatively, if they talked about how they typically used head-mounted displays in client meetings, I would classify it as relevant because it could potentially tell something about the ostensive aspect of organizational routines. All the transcribed passages of text were given a time stamp.

The 19 interviews from the second longitudinal data collection phase were transcribed by a professional transcriber. Before choosing a transcriber, I sent out interviews to a handful of selected and professionally relevant transcribers (e.g. having an educational background from the AEC industry), to test how they transcribed the audio into text. After selecting a transcriber, based on the initial transcriptions, I instructed the transcriber how to transcribe the interviews by creating a transcription manual they could use in case they did not understand for example abbreviations, and which also specified how they should make notations in the transcription in case of unclear audio passages which I could later revisit to clarify. The interviews were transcribed in the same manner as the interviews from the first explorative phase, with a few differences. That is, they were all transcribed word for word but excluding repetitions and intonations unless they had a significant impact on the meaning of a passage. However, unlike the first transcription, everything was transcribed in full, from the start to the end of the interviews, leaving nothing summarized. While this led to more work in the subsequent analysis, it was seen as the preferable option as these transcriptions were to be used in a more in-depth analysis. All of the transcribed passages were given a time stamp, as was the case for the initial transcriptions.

Lastly, the observations collected during the field work were organized in a chronological order. After an initial analysis of the first three interviews, done in the initial stage of the field work, the identified organizational routines, the organizational design routine, and the organizational meeting routine were grouped as one of the two aforementioned organizational routines. The observations that did not belong to any of the two organizational routines were left in a chronological order for later potential analysis. The documents and other artifacts collected were grouped into the respective construction projects they belonged to.

5.2.2 Thematic analysis

The three types of data was analyzed using thematic analysis (Boyatzis, 1998; Kvale, 2007). According to Boyatzis, thematic analysis is the process of coding qualitative information with the aim of developing a list or a model of themes. A theme is, more precisely, *"... a pattern found in the information that at minimum describes and organizes the possible observations and at maximum interprets aspects of phenomenon"* (Boyatzis, 1998, p. 4). These observations can be found at two different levels, the manifest or the latent level. The manifest level refers to themes that are directly observable in the data or information while the latent level refers to patterns that are not as readily available and requires more interpretation – such patterns are underlying phenomena.

Different approaches exist to the identification of themes which can be placed in a continuum (Boyatzis, 1998). At one end of the continuum, themes are generated from theory – a theory-driven or deductive approach. At the other end is the inductive or data-driven approach. In the middle of the continuum, Boyatzis places the prior data-driven or prior research-driven approach. All of these approaches are equally acceptable. All the approaches start out with the coder being, at least, conscious of theory or assumptions. but all the approaches: *"...differ in the degree to which the thematic analysis starts with a theory or the raw information"* (Boyatzis, 1998, p. 29). The theory-driven approach starts with the researcher using the theory directly by formulating signals, or indicators, of evidence that are explicitly linked to any given concept. Then the researcher proceeds by finding these elements in the "raw" data to identify themes that can for example explain why a phenomenon happens, or to explain a relationship between two phenomena. When doing an inductive analysis, at the other end of the continuum, the researcher identifies themes that developed from the raw data based on the actual words of the interviewees. The prior data-driven or prior research-driven approach typically exists when the researcher constructs thematic codes on the basis of a review of literature by using for example another researcher's existing code, findings, or (refuted) hypothesis. These are then used to find new themes on the bases of one's own data.

For this thesis I have predominantly employed a theory-driven approach. That is, for both analyses, conducted on the data collected in the first and second phase, the primary focus has been on the actors repeating performances and their typical pattern actions performed using technologies in general, but head-mounted displays and/or immersive VEs in particular. In short, the focus for both analyses has been on identifying organizational routines and technologies and how they have imbricated to influence each other. And the different aspects of these theories, especially the concepts from the organizational routines theory, have served as the foundation of both analyses. Thus, the concepts were used as sensitizing devices to identify themes in the data. Sometimes the theory, for example the organizational routines theory or the immersion theory, was reread before analyzing the interviews while at other times, it unconsciously served as a guide, informing me and helping me to understand the data phenomena. Therefore, I argue that I have mainly been using a theory-driven approach, although with some elements from the prior research-driven approach.

In the following two sections, I will elaborate on the process I went through to develop the aforementioned themes.

5.2.3 First phase: the analysis process for the exploratory data

The first 5 interviews, which were collected in an exploratory manner, were analyzed using a method called meaning condensation which was subsequently used to develop themes (Kvale, 2007; Walsham, 2006). These themes were developed going through the following steps.

First, I read an interview transcription, from start to end, to get a holistic understanding of the interview. Second, I defined and chose relevant meaning units (text samples) that were relevant to the focus of my thesis, namely organizational routines, immersive technologies with a particular emphasis on head-mounted displays. Sometimes I reread the definition of organizational routines or of immersion so that I could identify relevant passages of text and make data-theory links (Walsham, 2006). Third, I then stated, in a column next to the meaning unit, as briefly as possible, the theme dominating that particular meaning unit. In a fourth step, I asked questions to these identified meaning units in terms of the specific purpose of my study. Because the main research question of my study is to identify how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines the themes of each meaning unit were addressed with such questions as: What does this passage say about the use of head-mounted displays? Or how do or don't head-mounted displays change the relationship between clients and architects? Or how does the surrounding technical infrastructure imbricate with the organizational routine? In a fifth and last step, I tied together the relevant themes into a descriptive statement.

The following example illustrates how the meaning condensation method helped to develop themes. After reading through the interview with General Contractor B, I gained a holistic view of the structure of the interview, how it developed, and what parts of it that might be relevant to the research question of my thesis. Then I identified relevant natural meaning units. I organized the natural meaning units in the left column of a table and in a third step, I formulated the central theme in the right column of the same table (see Table 11). The natural meaning unit was seen as relevant because of the following factors. First, the interviewee is explicitly talking about an organizational meeting routine, the sales process, where head-mounted displays are used.

The natural meaning unit	**The central theme**
Right now, where we think VR brings the most value is in the sales process. If clients come to visit us, we… can make visualizations really quick from the model to the VR-goggles, so that they can walk around in their model. And the clients that have tried this think it is really cool. And we are using the ViVE [a type of head-mounted display]. Compared to the Oculus [another type of head-mounted display], it helps with the nausea because you can move around physically instead of sitting statically on a chair. That actually helps. We have actually experienced that some of them have been inside a model around an hour…. And then we have experienced that architects have commented on some peculiar things…	Head-mounted displays provide value during the organizational meeting routine by letting clients walk around.

Table 11: Example of meaning condensation.

The interviewee also talks about how they use a head-mounted display in turn providing insights into how the head-mounted display influences the actors in that particular organizational routine. In a third step, I identified that the main dominating theme was about the value that the head-mounted display provided to the organizational meeting routine by letting clients walk around instead of just sitting on a chair, as formulated by the interviewee. Next, I saw this particular meaning unit as relevant because it provided some idea of why they were using head-mounted displays in the organizational meeting routine in the first place – and even some of the potential drawbacks that they had previously experienced. Lastly, I provided a descriptive summary of all the relevant and central themes which could help to answer the research question.

5.2.4 Second phase: the analysis of the longitudinal study

The development of themes and the subsequent codes for the themes followed Boyatzis' (1998) three steps for developing theory-driven approach before being used on the data from the longitudinal collection phase.

In a first step, I developed the codes by reading the theory. A code in this context may be: a list of themes or patterns, a model built out of themes, indicators, and qualifications that are causally related. When generating codes, they should at least have the following characteristics in order to be meaningful. First, they should have a label (e.g. a name). Second, the code should have a definition of what the encoded theme is about. Third, a code description should be made which should help me as a coder to identify when a theme occurred in the data such as specific indicators. Fourth, a description that defines inclusion and exclusion criteria should also be provided to help identify the theme – possibly in the same description. Fifth and lastly, the description should also indicate some positive and/or negative examples in order to eliminate potential confusion.

For the generation of the codes, and for the later application of them, I used NVivo. The codes that I generated were drawn from the theories that I used, organizational routines theory and the imbrication lens. To encompass both, the main criterion was to generate a code that could encompass the performances of humans and/or technology. By focusing on the performances of humans and/or technologies, I was able to for example encompass both for the performative aspects of organizational routines. But by generating a code for actions, I could also encompass the main conceptual building blocks of the imbrication lens, namely the agencies of humans and technologies, which I could later build on to identify how they imbricated and influenced (afforded or constrained) each other to create an infrastructure of technologies and organizational routines. However, to also encompass the ostensive patterns of organizational routines and the technologies, which was not being e.g. talked about as being part of any organizational routines, I created an additional code for these two concepts. In this way, the code technology could also maintain the distinction between what a technology is (e.g. when an interviewee talks about a technology that is not necessarily enrolled and used in an organizational routine) and what it does (e.g. when an interviewee talks about how a technology is used in an organizational routine). Lastly, the codes labeled: “Performative actions”, “Ostensive patterns”, and “Technology” were put into two organizational routines labeled: “Design routine” and “Organizational meeting routine”. In all, eight codes were made but the latter two were only used as containers for the other codes.

For each of these eight codes I created labels, definitions, and descriptions in accordance with Boyatzis' (1998) recommendations. In particular, NVivo provides two fields for each code (“Node”), in the first of which I wrote the label (called “name”), and in the second I wrote the definition and descriptions for each code.

In a next step, the codes that emerged from the previous step were reviewed and if necessary revised in order to assess their compatibility with the data collected. This step is important in order to check if the codes are applicable or relevant to the data collected. The divergence in what is focused on in for example the data and the coding (concepts) cannot be too great. However, as mentioned in the section on data collection, early in that process I deliberately focused on the performances or actions of the actors in the organizational routines, both in the interviews and in the observations.

In a third and last step, Boyatzis (1998) stresses that the reliability of the code needs to be determined. In particular, he emphasizes: *“Reliability is consistency of observation, labeling, or interpretation”* (Boyatzis, 1998). This is of particular importance if more than one person is involved in the coding process. However, the generation and subsequent application of these codes was performed solely by the author of this thesis. Despite of this, Boyatzis stresses that no matter how the codes were generated, and the epistemology and ontology were employed, when utilizing thematic analysis as a method, the following three criteria are important to create consistency of judgment.

The first criterion is to create consistency among viewers. This criterion is achieved when different people see the same themes in the data and is therefore highly dependent on the way that information is recorded and what is chosen to be recorded, so that others such as experts within the same theoretical field can pass the same judgments by for example rehearing the same recordings. Thus, as stated in the data collection section, I captured all interviews, except one, through audio recording. I could then rehear the interviews and hence increase the likelihood of judging the consistency of the codes. In addition, by asking the interviewees to confirm my categorization of their actions into the two aforementioned organizational routines, in the first interview round of this second phase, I also increased the likelihood of interpreting the data consistently. Other ways in which I tried to increase the consistency of judgement included using a largely standardized interview guide and: *"…ascertaining information from the various people, organizations, moments, or whatever forms the unit of coding and the units of analysis in a way as to increase the feasibility of determining consistency of judgement among multiple observers or researchers"* (Boyatzis, 1998, p. 147). In other words, by interviewing a large majority of the employees in the organization, the chance of achieving consistency of judgment has increased. Lastly, it was also sought to improve the consistency of the generated codes and themes by presenting the data at the European Group of Organization studies where other researchers within the field of organizational routine studies could provide feedback to my interpretations of the collected and analyzed data.

A second criterion relates to whether or not the data collected is consistent over time and events. I have sought to encompass this criterion by collecting longitudinal data. This way, the encoding of the data and the themes derived from it should help to establish consistency of judgment because the data was collected over a six months' period, thus enabling a potentially more comprehensive view on the actions of the employees and technologies.

A third and last criterion relates to the researcher's confidence in judgments of the codes and that these have captured the phenomenon of interest. Here Boyatzis (1998) refers to triangulation as an important way to increase the confidence in the judgments. In this second phase, I have sought to incorporate this criterion by triangulating through three types of data: observations, interviews, and artifacts.

Once these criteria for consistency of judgment were established, I applied, in a next step, the generated codes to collected data. First, I sought to identify the ostensive patterns of organizational routines in which head-mounted displays were utilized (Pentland and Liu, 2017). The second stage involved identifying the imbrications of humans and technologies by looking for their respective actions. Both steps are elaborated on in the following paragraphs.

I coded the data using NVivo. Specifically, I did this by identifying actions from the interviews and observation data (Pentland and Liu, 2017). In relation to the definition of organizational routines, actions that did not occur more than once (repetitive) in the data was not included. The actions were coded as the same organizational routine if they had the same purpose despite small variability (Pentland and Liu, 2017).

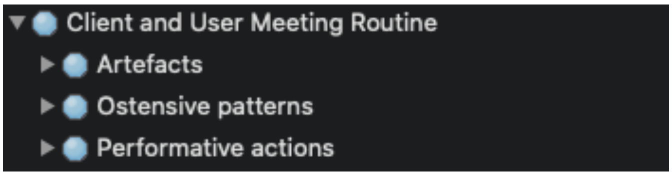


Figure 13: Example of codes for the Organizational meeting routine.

In a next step, the actions within each of the two organizational routines were ordered into a narrative or a logical sequence (Pentland and Liu, 2017). The sequencing was based on observations and the accounts of the interviewees.

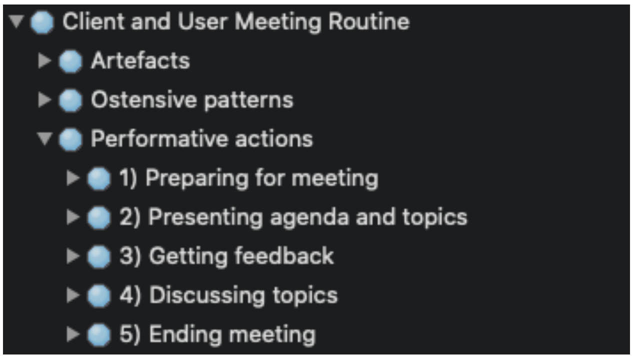
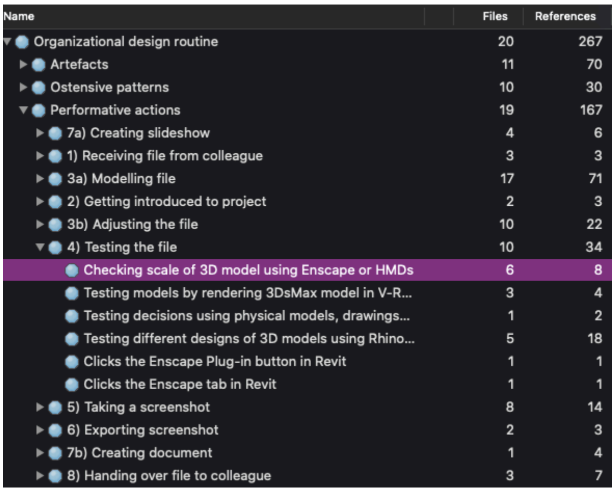


Figure 14: How the actions of the organizational meeting routine were sequenced.

The intertwining of humans and technologies was then identified by analyzing the performances of the two organizational routines. As before, I analyzed the data by employing a theory-

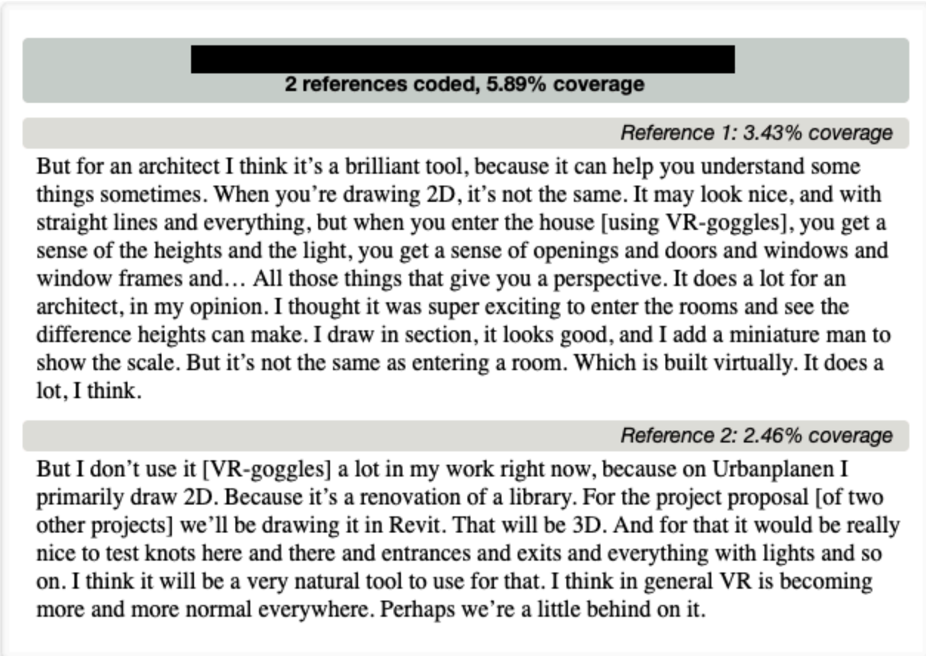
driven method by first reading and analyzing the performative codes for each organizational routine while consulting the conceptual definitions by Leonardi (2011) to identify imbrications of human and material agency.

This analysis was done in two steps. First, within each of the two organizational routines, the codes that mentioned immersive technologies, in all three categories shown in Figure 14, were selected and analyzed to detect whether the immersive VEs or the head-mounted displays were affording or constraining the performances of the organizational routine. For example, from the code "Checking scale of 3D model using Enscape or HMDs" (see Figure 15) I find a reference (a passage of text) which tells me something about the agencies of head-mounted displays and architects (see example in Figure 16). During this step, I continually went back and forth between the concepts and the empirical data.



Name	Files	References
Organizational design routine	20	267
Artefacts	11	70
Ostensive patterns	10	30
Performative actions	19	167
7a) Creating slideshow	4	6
1) Receiving file from colleague	3	3
3a) Modelling file	17	71
2) Getting introduced to project	2	3
3b) Adjusting the file	10	22
4) Testing the file	10	34
Checking scale of 3D model using Enscape or HMDs	6	8
Testing models by rendering 3DsMax model in V-R...	3	4
Testing decisions using physical models, drawings...	1	2
Testing different designs of 3D models using Rhino...	5	18
Clicks the Enscape Plug-in button in Revit	1	1
Clicks the Enscape tab in Revit	1	1
5) Taking a screenshot	8	14
6) Exporting screenshot	2	3
7b) Creating document	1	4
8) Handing over file to colleague	3	7

Figure 15: A code from the organizational design routine.



[redacted]

2 references coded, 5.89% coverage

Reference 1: 3.43% coverage

But for an architect I think it's a brilliant tool, because it can help you understand some things sometimes. When you're drawing 2D, it's not the same. It may look nice, and with straight lines and everything, but when you enter the house [using VR-goggles], you get a sense of the heights and the light, you get a sense of openings and doors and windows and window frames and… All those things that give you a perspective. It does a lot for an architect, in my opinion. I thought it was super exciting to enter the rooms and see the difference heights can make. I draw in section, it looks good, and I add a miniature man to show the scale. But it's not the same as entering a room. Which is built virtually. It does a lot, I think.

Reference 2: 2.46% coverage

But I don't use it [VR-goggles] a lot in my work right now, because on Urbanplanen I primarily draw 2D. Because it's a renovation of a library. For the project proposal [of two other projects] we'll be drawing it in Revit. That will be 3D. And for that it would be really nice to test knots here and there and entrances and exits and everything with lights and so on. I think it will be a very natural tool to use for that. I think in general VR is becoming more and more normal everywhere. Perhaps we're a little behind on it.

Figure 16: The code "Checking scale of 3D model using Enscape or HMDs".

In the second and last step, I sought to identify whether some of the performances with the immersive technologies were repeated, recognized, and therefore retained in the ostensive pattern of any of the two organizational routines under investigation. The aim of this was to see whether or not the technology constrains or affords the performances of the architect.

In this manner, I could deduct, from the interviews as well as the other empirical sources, how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

5.3 Reflections on data collection and analysis

In the following sections I reflect on the limitations of the chosen methods for data collection and analysis.

5.3.1 Data collection, analysis, and theory: reflections on how they fit together

The main unit of observation of this thesis is the doings of human actors and technology. This is because I use an ontology which sees the world as consisting of human and material agencies.

For this thesis I have aimed to maintain the same ontological underpinning both when choosing theory and when choosing data collection and analysis methods. To elaborate on the former, the ontological underpinning for the organizational routines theory and the imbrication lens both build on an ontology where the main unit of observation is the doings of humans and technologies and what they do together when intertwining. When collecting data, I have utilized primarily interviews and observations. For these two data collection techniques, I focused on the doings by employing for example interview guides that ask about how they model a 3D building using a head-mounted display. During observations, particular focus was on two organizational routines and how they, together with immersive technologies, perform these organizational routines. And when analyzing, the primary focus has been on the actors' repeating agencies and their typical patterns of actions done together with technologies in general, but head-mounted displays and/or immersive technologies in particular. In short, focus for both analyses has been on identifying organizational routines and immersive technologies and how they have intertwined and influenced each other.

A potential limitation of the imbrication lens is its illustration and depiction of the interlocking imbrications of human and material agency which can result in a too simple and linear representation of an otherwise highly complex relationship. The illustration can, in other words, resemble a waterfall model where the process of imbrications is depicted in a sequential and orderly process. However, in practice this is seldom the case. Instead, it is often a messy and highly iterative process when organizations enroll or un-enroll any given IT technology, as much IS research has already pointed out (Cecez-Kecmanovic et al., 2014; Orlikowski and Scott, 2008; Robey et al., 2013, 2012).

The data collected in this thesis also shows that the interactions of technology and organizational routines was also a highly messy and iterative process. When collecting the data, I tried to capture the complex interactions of technology and organizational routines by utilizing an explorative approach in the first phase of data collection and analysis, and by initially conducting explorative interviews in the second phase. In this way, by utilizing these methods for data collection and analysis, I aimed to do a linear and sequential analysis in the second longitudinal phase where the imbrication lens was employed. Another strategy I employed was to utilize three types of data in the analysis for the second phase, namely interviews, observations, and documents. Doing so, I tried to confirm or disconfirm my assumptions by comparing my findings in one type of data with another when applying and identifying themes in the analysis of the longitudinal data.

One could argue, however, that observation as a method might not fit a rather rigid theory-driven approach such as the imbrication lens because many nuances are lost. However, I argue that choosing to combine observations with the imbrication lens helps to strike an appropriate balance between being open while also making sense of the large amount of data that such a method can produce. In practice, I aimed to do this by for example trying to draw on all of the different types of data during the analysis of the longitudinal data. And when using this data, I often used and inserted longer quotes which served as a way to make the depiction and analysis more nuanced by allowing readers to make their own interpretations and judgments of the quotes. In this manner, I aimed to be open to any new themes that might occur and not to depict the enrolling and subsequent retention of the immersive technologies as a linear and rational process, while balancing that with an aspiration to make sense of a rather large amount of data in such a way that I could answer the research question within a limited amount of time.

5.3.2 Limitations

This thesis has some limitations, however. First, I have collected data from only five organizations within the AEC industry. This can potentially limit the reach of the results of this thesis. However, it is important to note that the epistemological assumptions on which this thesis is based do not aim at statistical generalizations, by for example creating theoretical concepts that account for and explain why all current and future head-mounted displays are used or not. Instead I seek to produce theoretical generalizations that travel across contexts by explaining *how* dynamics and relations in one context can guide actions in other contexts. With the findings identified in this thesis, I can offer insights for understanding: *"…other situations while being historically and contextually grounded"* (Orlikowski and Feldman, 2011, p. 1249). For example, identifying how the inclusiveness of head-mounted displays prevents organizations from enrolling and retaining the head-mounted displays in the ostensive patterns of organizational routines, means that other organizations will be able to see in what situations head-mounted displays can potentially immerse their users. Or other scholars who aim at investigating can apply and further build on a performative view on immersion as a concept to understand future immersive technologies.

In addition, scholars within organizational routines research and also within other related areas such as sociomaterial research suggest collecting data produced by the artifacts themselves, for example from software logs (Cecez-Kecmanovic et al., 2014; Feldman, 2016). Such type of data could also have been relevant to this thesis as it directly relates to and shows the agency of the technology, which in turn could shed light on how humans and technologies interact. For example, by gathering data from the software logs of the CAD software, to which the head-mounted display is connected, it could have been possible to gather data going back before I started my data collection. Combined with interviews or observations, the data could for example have been used to shed more light on how and when head-mounted displays are used or the data could provide an alternative view on what actions the identified organizational routines have.

5.4 Summary

In this chapter I have presented a description of the data collection and the subsequent data analysis. Both the collection and the analysis of the data consists of two phases, an initial one, e.g. the explorative phase, and a subsequent one, e.g. the longitudinal phase.

The data from the first phase was collected using explorative interviews in five different organizations. The data from the second phase was gathered by doing 19 interviews combined with observations and the collection of artifacts such as documents, renderings, and relevant 3D files.

The interviews from the two phases were then transcribed and analyzed using thematic analysis with a theory-driven approach. The thematic analyses differed. The interviews from the first phase were analyzed through the method of meaning condensation, and the data collected in the second phase were analyzed initially by identifying themes and then by coding the themes in accordance to the theory on organizational routines and the imbrication lens.

I end this chapter with a reflection on the limitations of the methods chosen for data collection and analysis, and how these might not fit with a theory such as the imbrication lens.

6 The first explorative phase: analysis and findings

This chapter presents the analysis and findings of the first explorative phase. The analysis shows how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines in five different organizations, predominantly within the AEC industry. From this analysis I aim at identifying themes that can help to answer the aforementioned research question.

6.1 General Contractor A

General Contractor A operates in most parts of Northern Europe. And it covers all the phases of a building projects – from design to construction. The head-mounted displays were part of a greater management initiative to digitalize their processes through a method called Virtual Design and Construction which was initiated around 2010. While the contractor had invested resources in head-mounted displays and related software, the enrolling of head-mounted displays was not as big a success as in the case of the other general contractor.

The following two sections show how employees and head-mounted displays influence each other. The analysis covers a period from 2010 to 2017 and it shows a less successful attempt to enroll a more immersive technology into an organizational meeting routine.

In 2010, the general contractor started to implement a new management method called Virtual Design and construction[7]. With this method they sought to ease collaboration between the many actors (e.g. engineers and architects) that are often involved in a building project, by integrating work processes and sharing 2D and 3D models across these actors. By enabling a more collaborative environment, they hoped to be able to involve clients more easily in the design and building phase, with the aim to improve their product, the design, and the construction of buildings, while also being able to sell more to the client during the project design phase.

With this implementation of a new management method, they also aimed to enroll a technology into the organizational meeting routine that could help them to communicate their 2D and 3D models more intuitively to laymen and professional clients. They typically communicated the 2D and 3D models to clients by displaying the models on traditional monitors, by showing them

[7] Virtual Design and Construction (VDC) is the management of integrated multi-disciplinary performance models of design-construction projects, including the product (e.g., facilities), work processes and organization of the design - construction - operation team in order to support explicit and public business objectives (Kunz and Fischer, 2009).

printouts of these models, or by creating physical mock-ups. However, in 2015 they started to experiment with more immersive technologies, in the form of a simple head-mounted display.

The head-mounted display was simple in the sense that it consisted of a physical casing with a slot, into which a smartphone could be fitted. Consequently, the smartphone acted as the display that the user looked at when she had fitted the casing to her head. Therefore, it did not need to be connected to a desktop computer to run the immersive VE, as it relied on the smartphone to do the processing. Furthermore, the platform that they were using potentially allowed others to follow what the user was seeing while using the head-mounted display:

> *"This platform also makes it possible to sit on a computer next to the person wearing the VR-goggles, and if you start the same project on the telephone and on the computer, then you can see* [on a monitor] *what the user can see who is wearing the VR-goggles. And you can interact with the person who is wearing the goggles."* (Group interview – interviewee 2).

Compared to the monitor and the printouts, e.g. plan drawings, this head-mounted display is potentially more immersive. This is primarily due to the head-mounted display's ability to physically shut the visual sense of the user off from the surrounding environment (inclusiveness) while at the same time enabling her to look around by moving her head instead of using e.g. a controller. While a physical 1 to 1 model that shows e.g. the layout of a room in a future building is more immersive and can make the user feel as if being in a future building physically, the interviewees mentioned that these models are expensive to make. For these reasons, they wanted to introduce the head-mounted display as an alternative to the aforementioned technologies so that they could involve clients more in the organizational meeting routine.

In other words, the materiality of the head-mounted display, its physical and digital form and matter, provides a new material agency that allows the client to become immersed. And by providing a more immersive experience to clients, the head-mounted display could potentially resolve the limitations they saw in their current technologies.

> *"*[We want to] *use it* [the head-mounted display] *in our interaction with our customers. It has to improve the experience of customers so that they can make sense of our models… The main reason for us doing this is to provide a*

> *better product to the client while also maybe sell more."* (Group interview – interviewee 1).

Hence, the interviewee stresses that their main intention in enrolling a head-mounted display in the organizational meeting routine is to create a better product, while being able to sell more to the clients during the design phase of a building project. And as mentioned, the current technology used does not provide an immersive experience to clients. So, in order to resolve the constraint, they need to use it in the interactions with clients, which usually take place in clients' project organizations where the right people with authority to make decisions are.

6.1.1 Un-enrolling the head-mounted display of the organizational meeting routine

The head-mounted display, and its related hardware and software, can more precisely help the employees by making 3D models more understandable to laymen and even professional clients as it makes it possible for them to walk and look around in a more natural manner than when using the previous technologies. In addition to this, it can also create a relatively detailed and vivid immersive VE to the users. Together, these factors have, in some instances, helped them to involve clients more in the design of construction projects. For example:

> *"In a project, a hospital* [project]*, they* [the project organization] *put in a picture* [into the head-mounted display] ... [which gave the impression of] *lying in a bed* [to the user of the head-mounted display, an architect]*. By doing this, the architect found out that the wall under the window should be lowered because otherwise, the patient couldn't look out the window. But we still need to spend resources on helping the clients that are going to use VR."* (Group interview – interviewee 2).

The example shows how the head-mounted display, and its related hardware and software, enables a professional client, an architect, to better understand a 3D model by providing a sense of scale. However, the interviewee also finishes his example by stating that they still need to spend a lot of resources on helping the clients to use the head-mounted display.

The interviewees explain that this is the main reason why the head-mounted display has not become a viable alternative to the other technologies in the organizational meeting routine. Thus, even though they have used it in some instances as the above example showed, it has not helped them in the way they intended: to involve clients more in the different project organizations, which was stressed by the interviewees. Accordingly, while they see the use of head-mounted displays in the organizational client meeting routines as potentially beneficial, due to their ability to among other things walk and look around in a natural manner, the actual use in the rest of the organization is limited. The interviewees point to technical reasons for the limited use of the head-mounted display. For example, when the interviewees tried to demonstrate how they used the head-mounted display during client meetings, the it could not load the 3D model of the building due to a slow Wi-Fi connection. Therefore, it took some tries to get it to load the 3D model, which prompted the following reaction from the interviewee:

> *"This is exactly what can destroy progress. If it* [the head-mounted display] *doesn't work people won't use it. And if you need specialists to use the head-mounted display or to help others use it, then it becomes too costly."* (Group interview – interviewee 2).

The interviewee explains that the head-mounted display, and the surrounding technical infrastructure it is connected to, has to be easy to use and be able to work in many different contexts – it needs to be flexible. But another contributing factor that attributed to the head-mounted display not being a viable alternative to the other technologies also related to the human factors. Importantly for this organization, it seemed that the employees in the project organization did not want to invest more resources in the roll-out of the head-mounted display due to costs associated to it:

> *"…we have tried to use VR* [the head-mounted display] *in the proposition phase in a couple of projects but we haven't really been using it that much. We have some trouble getting this integrated into our processes because it costs extra resources and the architect needs to be in on it as well and so forth…"* (Group Interview – Interviewee 1).

In particular, he stresses that they do not possess the right technical competences in that division of the organization. Consequently, when the project organization has to use the technology, they have to outsource e.g. the production of 3D models to another company which makes the costs quickly add up.

In short, because of the head-mounted display, the surrounding technical infrastructure it is connected to, but also due to the lack of skills and know-how in the organizational routine, the ostensive pattern that the affordances of the head-mounted display are part of, is not maintained in the organizational meeting routine in this company.

6.2 General Contractor B

General contractor B is situated in Northern Europe. It offers services within the architecture, engineering, and construction industries, covering all phases of a building project, from design to construction. At the time of the group interview, in 2017, they had invested in and allocated dedicated resources to initiatives that could help to make their organizational routines more productive, among other things. Accordingly, they had one technical employee as well as a manager both of whom were given time and resources to invest in e.g. the implementation of head-mounted displays.

The following account chronologically shows how a head-mounted display influences the employee's performances and is enrolled into an organizational meeting routine during a period from 2012 to 2017. The intent with this analysis is to show how a head-mounted display, and its related hardware and software, changes and subsequently comes to matter in their organizational meeting routine.

6.2.1 Enrolling a head-mounted display in an organizational meeting routine

Since 2012, architects and engineers have been using VEs produced by CAD software to sketch and design 2D and 3D models of buildings. They have used these tools to present and explain projects to clients in an organizational meeting routine. They do this at different stages of a building project. In the beginning of a building project, they present the project introducing the clients to the design of the building or, if later in the process, they have client meetings to present project updates to the clients. They use these client meetings to sell new building projects or additions to an existing project. The overall intention in this organizational meeting routine is to convince their clients so that they approve of their idea of a new building or any new additions to an existing project. In one project, for example, they argued with the client, an architect, whether or not they should install a railing on a staircase landing, which was important for safety reasons. But this addition might also be expensive to the client. And in order for the client to be convinced, the client needed to be impressed but more importantly, to be able to have the same understanding of the 2D and 3D drawings. And even though professionals, such as architects and engineers, can usually interpret these technical drawings as well as 2D and 3D models, the drawings or models require some level of interpretation which can result in misunderstandings. At other times, the clients might be laymen who had never been involved in a building project before, and in these cases, misunderstandings might also arise as they naturally had difficulties in interpreting these drawings or models.

As mentioned, these difficulties may lead to misunderstandings between the client and the general contractor, which in turn can create mistrust and an inefficient building process. Traditionally, 2D and 3D models were displayed on regular computer screens, and clients and users could move around in them using a keyboard or a mouse. To convince potential clients or to avoid these misunderstandings in the later stages of a process, clients are involved in the building project as early on in a project as possible. However, it does not always suffice to show previous technology such as 2D plan drawings and even the aforementioned 3D models to future clients.

The employees of this organization therefore saw the current technology as restraining the performances and the idea of the organizational routine. In particular, as they wanted to reduce misunderstandings, they regarded the current way of communicating to clients, through 2D and 3D models shown on traditional monitors, as inadequate because it was not immersing their clients to the degree they now wanted. That is, the computer monitors on which they used to show 2D and 3D models did not provide an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of the client. As a consequence, misunderstandings and mistrust could arise between the general contractor and the client and at that time, they regarded this as being too big of a problem with the current technologies.

To handle this problem, they decided to complement the other tools with a head-mounted display.

Initially in 2015, however, they did not succeed in enrolling a more immersive technology as it required too much development effort, as the following quote illustrates:

> *"We started to use VR in 2015 – slowly. Back then there was a lot of development work. There were not a lot of default applications so we had to use Unity or Unreal* [standard 3D graphics engines] *and build our own base* [software] *on that. So, at that point we looked at it but we moved away from it."* (Group interview – interviewee 1).

The head-mounted display they looked into in 2015 required that they developed their own software which, despite their new goal, would require too many resources to enroll into their existing organizational meeting routine.

They therefore decided to initially buy and use a cheaper head-mounted display that did not require a lot of resources. But after some time, in 2016 they identified a plug-in that was compatible with their existing software and which could convert their existing models so that they became compatible with a new and more advanced head-mounted display.

This new head-mounted display was easier to enroll into the existing organizational meeting routine as they only needed to install the plug-in on their existing CAD software to make their existing 3D models compatible with the head-mounted display. In this fashion, clients could be immersed in existing 3D models. The head-mounted display itself was wired to a computer. When a client put it on during the organizational meeting routine, she was also handed a pair of controllers which she could use to walk, jump, or fly around. And because of sensors around her, she was able to move her head and look around in for example a 3D model of a house. While she was doing this, what she saw when wearing the head-mounted display was also shown on a computer display. In this manner, others could potentially follow what she was doing.

The head-mounted display, and its related hardware and software, differentiated itself from the existing technology as clients could potentially understand designs better while attending a client meeting. This was especially due to the head-mounted display's ability to potentially provide users with a panoramic view, while the materiality of the head-mounted display shut out the physical surrounding environment, together with its ability to make clients look around in 3D models in a natural manner. In all, these abilities to surround, be inclusive, and match client body movements, made it easier for clients to experience a sense of scale when immersed into a virtual building. Consequently, by supplementing the more immersive technology with the existing ones during the organizational meeting routine, they increased the chances of clients better understanding a given building project.

In short, prompted by the aforementioned intention, this organization acquired a new technology which was enrolled and retained in the ostensive pattern of the organizational routine, in turn increasing the potential for immersing clients.

6.2.2 Retaining the head-mounted display in the organizational meeting routine

The interviewees showed excitement about the head-mounted display as it enabled clients to walk and look around while being shut off from the surrounding environment. One of the interviewees mentioned that the immersive VE that it facilitates provides a more physical experience to the clients, referring to the immersive technology's ability to let the client look around in a 3D model by moving their head – just as in real life. As the following dialogue between the interviewees illustrates:

Interviewee 3: *"So your experience* [with a client] *was that it was a very bodily interaction…?"*

Interviewee 1: *"Yes very much…"*

Interviewee 2: *"Physically walking around and going upstairs, opening doors, and going through doors… interacting with walls…"*

Interviewee 3: *"That is what it* [head-mounted display] *does differently… compared to when you just look at a screen."*

Interviewee 1: *"Yes. One example is… in a project we didn't have a railing on the landing of a staircase. So, when the architect* [client] *walked around in the model he accidentally fell down from the landing."*

Interviewee 3: *"In a virtual space…hopefully?"*

Interviewee 1: *"Yes, in a virtual space."*

Interviewee 2: *"And we had warned them about the danger of not setting up the railing, but they were somewhat against that proposal. So as interviewee 1 says, then the client walked around on the landing and he suddenly fell down. And because he experienced the falling with his body, he reacted as if he landed in real life. And it wasn't like a small reaction it was quite clear that he got genuinely surprised as he fell down. The falling felt real. And because of this incident he became convinced that this railing should be there anyway."*

Interviewee 1: *"So what we see is that they begin to interact more with the model."*
(Group interview – dialogue between interviewees).

The dialogue points out that the more immersive technology changed the way the clients understand 3D models by making their experience more physical. The walking and looking around made the 3D models, in some instances, easier to understand and helped them to achieve what they had intended with the head-mounted display by reducing misunderstandings between the client and the general contractor. Hence, the performances of which the head-mounted display was a part in turn became a variation which was retained in the ostensive pattern of the organizational meeting routine. This new variation, involving the affordances of the head-mounted display, modified the current ostensive pattern because the previous and less immersive technology inhibited their intention of reducing misunderstandings. The interviewee also noted that the modified ostensive pattern did not prevent them from guiding their future actions, indicating that it could be used to guide future actions of employees and clients while also legitimizing their past actions – as illustrated in the aforementioned quote.

This was due not only to the materiality of the head-mounted display and its material agency, which together provided clients with a more immersive experience, but also to the employees in the organization and their ability to experiment and integrate the immersive technology, which allowed them to integrate it into the existing ostensive pattern of the organizational meeting routine.

Their experience with the head-mounted display led them to conclude that it could be integrated into their existing ostensive pattern as it helped them to reduce misunderstandings.

6.3 Architect Company A

The architect company, located in Northern Europe, is involved in the planning and design phase of building projects. They started to use head-mounted displays as a complimentary tool during presentations to convince potential clients and already existing clients of new building designs or updates to existing ones. They first enrolled head-mounted displays in the organizational meeting routine in 2016. At the time of the interview, the enrolled head-mounted displays were a relatively new initiative.

The following sections describe and analyses chronologically, starting in 2016, how two different head-mounted displays were enrolled and eventually retained in the ostensive pattern of their organizational meeting routine.

6.3.1 Enrolling a head-mounted display in an organizational meeting routine

During the past 15 years, the company had slowly transitioned to design almost everything digitally. Traditionally, they had been using paper and pen, 2D and 3D CAD drawings shown on a monitor to show potential or new clients new additions or updates to a building design, respectively. However, as they had transitioned to predominantly designing and using traditional monitors instead of pen and paper, they had encountered a big issue.

With their current setup using monitors, clients quickly lost their sense of scale. As a result, important details could not be communicated properly to clients. As the interviewee explained it:

> *"Because the sense of scale you have when looking at a screen is pretty bad compared to a physical model or a virtual model* [shown by using a head-mounted display]*... If you have a banana here physically in front of you. You kind of know how big that is. If you have a* [virtual] *3D banana in a piece of software you can zoom in and out… you can get an approximation of the scale but it is never the same because you cannot experience it even though you can put in a scale into the model. You can train yourself to better grasp the scale. But to get a really good understanding you need to… it* [the experience of scale] *is at least much better in a physical 1:1 model or* [when using a head-mounted display to show] *a virtual reality model. That is one of the big things which we use it* [the head-mounted display] *for."* (Interview – architect).

In other words, to make the client understand their 3D models better, they were looking to complement their monitors with a head-mounted display during the organizational meeting routine.

In 2016 they were searching for relevant head-mounted displays that could help to improve how they communicated with clients. This search led them to a simple and mobile head-mounted display – the same type that General Contractor A enrolled in their organizational meeting routine. The head-mounted display changed or rather complemented the current related technology by acting as a way for their clients to experience scale rather than having it explained. At client meetings, they had typically brought with them one or more of these head-mounted displays.

The head-mounted display itself consisted of a casing into which a smartphone could be slotted. Hence, the smartphone acted as both the display and as the processing unit. Because of this, it could not run full 3D models but only show pictures from specific points in a 3D model. Hence, the head-mounted display gave the user the illusion that she was looking from a specific spot in a 3D model, e.g. from the outside of a building showing the form and size of the building:

> *"You design here and here* [pointing to a sketch of the design process, (Figure 11)]. *Here* [in the appraisal phase] *you make the conceptual vision and then you have a presentation for the CEO of some company or whatever. And at*

> *that stage we have used it quite a lot – this type of thing* [pointing to the simple head-mounted display lying in front of him]. *This head-mounted display utilizes rendered still pictures that shows the client how something looks at specific points in space. We have done that a lot of times. The benefit, of course, is that you get a much better experience of being there… it makes like a slideshow. But this thing… if you take the 3D model that we already have ready for a project which is already rendered in detail if you have set that up, there isn't a long way to go to set up a camera and then render it out and take e.g. 10 still photos of the project which you can take with you to a presentation. So, they* [the head-mounted display] *are also quite mobile."* (Interview – architect).

Like with the other types of head-mounted displays, it is its ability to shut the user off physically from the surrounding environment, its inclusiveness, as well as its ability to provide the user with the experience of looking at a surrounding or panoramic display, which makes it immersive to the user. And lastly, its ability to provide a vivid immersive VE to the visual sense of the user, while she has the ability to look around in a natural way by using her head, also has a significant impact on the potential feeling of immersiveness and thus increases the likelihood of feeling a sense of scale – as described by the interviewee. In this manner, the head-mounted display solved the constraints which the architects perceived that the existing technology had.

6.3.2 Retaining the head-mounted displays in the organizational meeting routine

In short, because the head-mounted display, and its related hardware and software, allowed the clients to look around they could better understand e.g. scale and potentially feel as if they were actually in the virtual 3D model. The head-mounted display in turn helped the architect firm to make the clients understand the scale of future building projects better, which could result in a more efficient building process, among other things.

However, the architect also expresses the following doubt about the head-mounted display:

> *"However, if we should mention one not so good thing about these* [pointing at the head-mounted display in front of him]*, and that is the same with every type of VR… it is you lose the people that are wearing the VR goggles and you cannot talk with them. So, when they are in there, they are in there. You can*

> *hear something, but you cannot see what they see… and you cannot really guide them. So, they are kind of on their own. I know that some are making different pictures in picture software, but it is hard to upscale. If 10 people are sitting in a room and everyone is using VR, they will all be very confused. So, it has been quite a challenge for us, for example during a presentation. If at a client meeting… how do you use VR when using it to present something? How do you use it practically? Because it also breaks the 'flow' when presenting a project. Because when you say: 'Now we are going into VR…'…but then people get a bit confused. And if you do not have enough devices, half of them have them on and the other half does not. This is a really big issue. So that is one of the drawbacks with these VR goggles."* (Interview – architect)

Despite of the challenges that the head-mounted display posed, the casing's matter, and the form of the head-mounted display, it became part of the organizational meeting routine.

In particular, they introduced the head-mounted display into the organizational meeting routine when less collaboration was needed. At other times the employees circumvented these challenges and used a more advanced head-mounted display which allowed them to connect it to a monitor. This in turn made it possible for the other meeting participants to see what the user of the head-mounted display was seeing:

> *"Generally, the big picture is that with VR, the potentially big issue is that it is difficult to collaborate around it. Because you are in there but the rest of us are not. Because right now it is pretty excluding. You do not see the same thing. With the HTC* [a more advanced head-mounted display], *you can add a monitor so that people* [other clients or employees present at the meeting] *can see what you see. That helps a bit of course, as you can guide the client. But it is still like: it is only one of them that can actually experience what he or she is seeing – the rest of them are just spectators… I think you need to be able to see the same thing at the same time, then it becomes something different. I do not think you should underestimate how much it matters to have an equal conversation about something…"* (Interview – architect).

By using a more flexible head-mounted display, or by using the more simple head-mounted display at strategic points in time where less collaboration was needed, during the organizational meeting routine, they were able to enroll the head-mounted display into the organizational routine. In these ways, they compensated for the inflexibility of the simple head-mounted display.

As a consequence, the head-mounted displays, including the surrounding technical infrastructure it is connected to, became an alternative variation to the other tools used in the organizational routine. In short, the ostensive pattern of which the head-mounted display, and its related hardware and software, was a part became legitimate and was thus continually maintained in the organizational meeting routine.

6.4 Architect Company B

Like in most of the other cases, this architect company is active in the architect, engineering, and construction industries. They are involved in the two first phases of a typical building process, the planning and design phases (see Figure 11). During a project, they are constantly in contact with the client they are designing the building for. They often meet face-to-face to discuss and agree on a project or any new developments of it.

They started to experiment with head-mounted displays in 2015. However, it was not until 2017, 3 months before the date of the interview, that they started to try and enroll head-mounted displays as a supplementary tool into the organizational meeting routine.

The following sections show how head-mounted displays, including its related hardware and software, and the actors of the organizational meeting routine influence each other, from 2015 to the end of 2017.

6.4.1 Enrolling a head-mounted display in an organizational meeting routine

The architect company sought to digitalize their building process, among other things due to a legal requirement. This requirement made it necessary for organizations within the architect, engineering, and construction industries to document the building process thoroughly in order for clients, and other third parties, to more easily identify who is responsible for specific errors or defects, if any such are discovered when the project is done. In particular, they sought to complement physical mock-ups with a digital 3D model because physical mock-ups are not so easy to document as changes cannot be tracked in the same detailed way that one can with virtual

3D models. In addition, physical mock-ups are often heavy and big in size, which makes them difficult to share with any third parties in case of liability claims.

However, the physical mock-ups are not easy to replace as they are especially good at making clients understand how future designs will look in a specific context – e.g. how the size and materials of a building fit in the surrounding environment. In turn, this helps clients to understand the concept of a building project or any changes to it. This prompts the company to find a new technology that can act as a complement to physical mock-ups in order to be able to involve clients in an efficient manner, while also being able to better document the design process.

In 2015 they acquired a head-mounted display. The head-mounted display was a more advanced one compared to those applied by some of the other organizations interviewed in this exploratory phase. The casing of the head-mounted display had an inbuilt display. But contrary to the more simple head-mounted displays, it needed to be wired to a desktop computer, in order for it to process and project the immersive VE to the client. In addition, sensors needed to be put up around the client which tracked the physical movements of the clients, making it possible for them to walk and look around in the VE using his or her legs and head, respectively.

This provided the clients with a more immersive experience due to especially the head-mounted display's ability to provide an inclusive and surrounding experience, as well as its ability to sense the physical movements of the user and project them into the VE.

Thus head-mounted display made it possible for the clients to both walk and look around in the VE. Furthermore, the head-mounted display also enabled clients to discover errors in 3D models because they were able to look and walk around in it.

Together, these capabilities of the head-mounted display can help the architect company to complement physical mock-ups with virtual 3D models.

6.4.2 Un-enrolling the head-mounted display of the organizational meeting routine

The material agency of the head-mounted display thus allows display users to look and walk around in 3D models, which potentially increases the client's ability to understand new buildings projects or any changes to it.

However, the architect company started to experiment with the head-mounted display by enrolling it in the organizational meeting routine of 4 construction projects. As the following section will show, though, the ostensive pattern of which the affordances of the head-mounted display were a part did not become an alternative ostensive pattern that was retained in the organizational meeting routine.

To elaborate on this matter, the head-mounted display, and the surrounding infrastructure, helped the clients to understand the context and scale, just as the physical mock-ups. But it also helped them to more easily document any changes or other relevant details of any given project. However, when they started to experiment with the head-mounted display in the aforementioned projects, an unexpected thing happened:

> *"*[In] *one case, the CEO of a building project was asked to use the VR goggles* [head-mounted display] *to review changes in a 3D model of a building. This first of all created a wow effect. But then he asked: 'Why is this part of the building like this?'. We had to explain that this* [part of the 3D modelled building] *wasn't the most updated version… Here we already came to understand a gap* [in our knowledge]*: When do we show which tings to our clients, and who do we show them to? Normally, we create pictures or renderings of buildings. And if there is a problem* [for instance an unfinished part] *with a building, we can e.g. put a tree in front of it. But* [with] *VR* [the affordance of looking and walking around] *reveals everything. If we put a tree in front of an unfinished part of a building, you can just look at or walk around it."* (Group interview – architect).

The client in this case had experience from the architect, engineering, and construction industries so in the specific instance, the unfinished 3D model did not have any consequences for the overall building process. But if, for instance, he requested them to figure out the details of the building but the details were not important at that point of the design process, it could end up delaying the overall design process:

> *"To what degree should the client be involved? We want the client to feel a part of the design process, but we want to be in control of the process. Involving them too much could cause a problem."* (Group interview – architect).

Hence, while they recognized the importance of involving the client in the planning and design process, they were generally quite skeptic about letting clients getting too involved as it could result in an inefficient design process, among other things.

In other words, head-mounted displays and the infrastructure they rely on can potentially become retained in an alternative ostensive pattern of the organizational meeting routine. However, it might end up being counterproductive to enroll and retain head-mounted displays into the organizational meeting routine.

The architect company consequently were cautious about enrolling it in the organizational routine. The alternative ostensive pattern that includes the head-mounted display could not be legitimized as a viable pattern by the employees for the organizational meeting routine. As a result, the head-mounted display did not entail any significant changes to the organizational meeting routine even though its use had the desired outcome. That is, it helped the architect company to make clients understand a building project in an efficient manner, and to document the building process in more detail. But, they did not enroll it into the organizational meeting routine of other projects as they would lose too much control of the planning and design process.

6.5 A Product development company

A product development company that develop ideas into products and subsequently market and sell them for other companies. They use a combination of physical and virtual prototypes to show how their clients' products could look like. They introduced the head-mounted displays with the main goal of aligning expectations with the client for whom they design a product.

The following sections chronologically explain how a head-mounted display, and the related hardware and software, is initially enrolled and then retained in an ostensive pattern of an organizational meeting routine. The description and analysis were started in 2014 and ended in 2017 – the date of the interview.

6.5.1 Enrolling a head-mounted display in an organizational meeting routine

To build virtual mock-ups of products, they had used 3D CAD software and physical prototypes. These virtual products were shown to clients who could then validate or ask questions about any given aspect of the products. However, if they were designing a fairly large product and a client had to look at a traditional display, then the client's ability to imagine the product was hampered. While physical mock-ups of future products could help clients to better understand the idea behind the products, the development of a physical prototype could potentially require more than double the resources of a virtual one. They were therefore searching for a way to reduce costs while still allowing clients to understand the idea behind the product, especially larger ones, they were designing for their clients.

Since 2014 they had used a simple head-mounted display with the aforementioned intention of aligning clients' expectations of products in a more effective way. The head-mounted display primarily enabled users to immerse themselves, due to the form of its material and the ability of its matter to shut users off from the surrounding environment (inclusiveness), its ability to provide a broad view instead of a narrow one (surroundingness), and its ability to project users' head movements into the VE.

When clients were provided with the possibility of being immersed in e.g. future products, the other technologies were regularly complemented to help them align clients' expectations as early as possible in the design of these products. At other times it also helped them provide feedback that could improve the product in an effective way compared to the physical prototype. For example:

> *"When we design fairly big things, we make* [virtual 3D models compatible with the head-mounted display] *... the prototype I showed you* [a physical prototype of an electric scooter] *that was made in foam. It costs 13,000 EUR. It is not free to make a VR model but that maybe only costs 2,000 EUR. And then we can also more easily adjust the VR model than the foam model. That is what we use VR for. We use VR to show to our clients what this big product looks like and how it is experienced in a 1:1 scale. For meetings where the CEO and his employees are present, I can for example have a box with 10 of these with me* [the simple and mobile head-mounted displays]. *Because we do not use more expensive equipment… I can hand out all these to the meeting participants and then say to them: 'Could you please download this application on your own smartphones?' ... I have tried sitting with CEOs from pretty big companies who look around* [wearing the head-mounted display], *and then they ask questions: '... does this mean that the door handle is placed at this height?... That doesn't work…' Then we can fix it. But they cannot see it when… they cannot see it when it is not in context."* (Interview – CEO of Product development company).

In this manner, head-mounted displays either replace or supplement physical models in the organizational meeting routine.

6.5.2 Retaining the head-mounted display in the organizational meeting routine

However, the enrollment of head-mounted displays into the organizational meeting routine was not without problems. They often observed that while the materiality of head-mounted displays enabled users to immerse themselves as they could focus their attention on the VE, the clients often felt uneasy when they were asked to put them on. This was especially the case when many people were present during meetings:

> *"It does take some convincing when customers have to put on a head-mounted display, due to vanity. In here* [internally in the organization] *we can look ridiculous wearing the head-mounted display. But when sitting with clients… when* [for example] *asking a CEO to look ridiculous with a pair of these VR goggles* [head-mounted displays]. *The first time one of our clients was about to use it I said to him: 'Open your smartphone and do this and that' he then did that. Then I said: 'Here you have a mask* [the head-mounted display], *please put it on'. And meanwhile all his employees are sitting in the room as well… but if the CEO can do it, we can as well. So that is how it sometimes works."* (Interview – CEO of Product development company).

To handle some of these "vanity issues" that could arise in situations where many people sit in a room together and only one person at a time can become immersed – or become immersed in separate VEs, the interviewee applied some strategies. For example, if a CEO and her employees were sitting in a client meeting, the interviewee would often ask the CEO to put on the head-mounted display first because that would help to alleviate the initial hesitance that the CEOs employees might show if they were asked to put on the head-mounted display first. Another strategy the interviewee used was simply to make sure that he had enough of these head-mounted displays so that the other meeting participants could become immersed as well and at the same time. In other words, to make up for the inflexibility of the materiality of the head-mounted display, they had to make changes to the organizational meeting routine, manifested in certain strategies. These strategies could then convince people to let the materiality of the head-mounted display shut them off from their colleagues.

In this manner, the materiality of the head-mounted display together with its ability to let its users look around in a natural manner changed the organizational meeting routine because it resulted in more feedback from the clients. That is, the ostensive pattern that included the head-mounted display could be legitimized as a viable alternative in the organizational meeting routine because fairly big products, such as the cruise ship parts, could be communicated to clients in a way that made the understanding of them more intuitive. Instead of being explained what these items looked like, clients could experience them. While they had some issues due to the materiality of the head-mounted display, it helped the organization to validate and align expectations with clients in an effective way.

6.6 Findings: three overarching themes

This first explorative analysis presents data from the first of two research phases of this study. From this I have identified the following three themes and condensed them from the previous sections.

In each of the five organizations it was first of all evident that the materiality mattered when the head-mounted display and the organizational meeting routine interacted. That is, no matter if the clients became immersed in the VE, the physicality of the head-mounted display conditioned its users in certain predictable ways across the cases, which mattered and played an important role in whether or not the head-mounted display was retained in the ostensive pattern of the organizational meeting routine. In each case, for instance, the head-mounted display's physical form and matter shut users off from the surrounding environment, causing different outcomes. In the case of General Contractor B, it worked in the intended way by immersing clients and by convincing them of certain design changes. While in the case of the Product development company, the clients required some convincing due to vanity issues when they were asked to put on the head-mounted display, being physically shut off from their colleagues.

Second, in the organizations where the head-mounted display was retained in the ostensive pattern of the organizational meeting routine, the inflexibility of the physical and/or digital matter and form of the head-mounted display was made up for by the flexibility of the organizational routine. For example, by only using head-mounted displays in less collaborative situations, Architect Company A managed to retain them in the ostensive pattern of the organizational meeting routine. This means, that the employees involved in the organizational meeting routine adapted to the inflexibility of the head-mounted display's matter and form, whereas in the case of the other architect company, they did not identify a strategy to allow for the materiality of the head-mounted display which resulted in them loosing too much control to the clients.

Third, and lastly, the existing technical infrastructure and organizational routines also matter, whether or not the head-mounted display is enrolled and subsequently retained in the ostensive pattern of the organizational meeting routine. In the case of General Contractor B, unintended things emerged which had to do with existing technologies and organizational routines. In particular, the head-mounted display they initially experimented with was not compatible with the existing 3D CAD software, the performances, and the ostensive patterns of the organizational meeting routine in which it was enrolled. This in turn made them conclude, initially in 2015, that they did not want to retain a head-mounted display in an ostensive pattern of their organizational meeting routine. However, at a later point, they added a plug-in to their existing 3D CAD software which made their software compatible with the head-mounted display. In this way, the head-mounted display ended up being enrolled in the organizational meeting routine due to the flexibility of the digital materiality. By contrast, General Contractor A did not succeed due to an inflexibility of both the technology and their organizational routines. In other words, because technical competences were required to operate and set up the head-mounted display, the head-mounted display was not retained in an ostensive pattern of the organizational meeting routine.

In conclusion, to enroll and retain head-mounted displays into an ostensive pattern of the organizational meeting routine, the technology and the organizational routines both need to be flexible so that they can continually adapt to the intentions of humans and to the materiality of the technology. However, the five cases are only indicative. To better understand how humans and technology influence each other over time, the following phase sheds light on the longitudinal aspect of organizational routines using the imbrication lens. I do this to unfold how primarily head-mounted displays including its related hardware and software, and their materiality, continually imbricate with organizational routines.

7 The second longitudinal phase: analysis and findings

This chapter describes how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. The first internal organizational routine is named the design routine while the external organizational routine is called the meeting routine.

The chapter is divided into two sections, each starting with a description of the ostensive narrative of the above two organizational routines. To reiterate, these ostensive descriptions are “typical” descriptions of the organizational routines, and many other possible ostensive narratives of the organizational design routine exist and coexist with these simplified narratives. They should therefore not be seen as the only way an organizational design routine could be accomplished but merely as one of many different perspectives, constructed from the fragments of other ostensive narratives, which are then aggregated into the descriptions of two ostensive patterns that aim to provide an overview of the two organizational routines.

After these two descriptions of the organizational routines, I analyze how the head-mounted displays, and other immersive technologies that they are connected to, interact and change the ostensive patterns of these two organizational routines. The analysis and findings are described in a chronological manner and thus provide linear descriptions of the interactions between human and material agency. While I have tried to describe the interactions and changes in an iterative and realistic way, the aforementioned factors can leave one with the impression that their interactions happened in an orderly and linear fashion but in practice, the imbrications of human and material agency are a highly iterative process or dance.

The intent with the following section is to strike an appropriate balance between on the one hand showing the emergent and unpredictable ways that humans and technologies interact, while on the other hand telling a narrative that shows how imbrications progressively interact. In other words, the aim is to show how the interactions between human and material agency can lead to a change in organizational routines or technologies.

7.1 The organizational design routine

The overall purpose of this organizational routine is to design artifacts such as 2D plans or elevation drawings, walkable 3D models of whole buildings, screenshots of 3D-rendered buildings, and the like, which can then be used in meetings with collaborators, clients, and users. The output of this type of organizational routine is typically in the form of slideshows, printed drawings, or a file containing a 3D model of a building. In the subsequent paragraphs I will describe how the ostensive pattern of the internal organizational design routine typically follows the subsequent steps.

First, the architect, the engineer, or the landscape architect either creates a new file, finds an existing file on her computer, receives a file from a colleague, or if it is a landscape architect, she calls a surveyor to get measurements for a plan drawing, for example. Next, a colleague introduces an existing file to the (landscape) architect or engineer and explains what she should design or how the file connects to the overall project. If the file is a new one, she coordinates with a colleague, as all projects are done in collaboration with co-workers. Subsequently**,** they design a new 2D/3D artifact(s) or adjust an existing one. In the next step, the architect/engineer discusses the 2D or 3D artifact(s) with a colleague and subsequently tests it.

At this point, the architect/engineer takes a screenshot of a 3D model illustrating, e.g., a collision between distinctive design elements, to show colleagues and clients the latest updates in the design of their project. The screenshot is then pasted into a slideshow or a document. The slideshow is used during a meeting with either a client, user, or collaborator. The architect/engineer exports, saves, and lastly hands over the file to a client, colleague, or collaborator. The handing over involves emailing it or uploading it to a shared database that can be accessed by all parties engaged in the project. The client, user, or collaborator can download it ahead of time to prepare for a meeting, or after a meeting for note-taking. Her colleagues typically continue working more on either the slideshow or the 3D artifact/file.

From this description of the ostensive pattern of the organizational routine and in the following section, I will identify the imbrications of the employees and the technologies that occur over time. Through these imbrications, I highlight the performative variations that include head-mounted displays in the organizational design routine. Thus, I will get to understand whether or not these variations will create a new ostensive pattern or modify or maintain existing ostensive patterns of the organizational routine. And whether this potentially new or modified ostensive pattern can be used for the employees to either guide future performances or account for past performances, or be used as a reference to current performances and thus become a viable alternative ostensive pattern.

This way, I aim to shed light on how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

7.1.1 Imbrication 1 (Human → material)

1) Change in the organizational routine creates a new human agency and a new goal[8].

In early 2008, 2D drawings were the preferred medium of the architects in the company and in the broad AEC industry. While these 2D artifacts are easy to create and modify using the 2D CAD software program, they are not always intuitive. Understanding the 2D artifacts requires reading the design first and imagining them in real dimensions. This requires extensive geometrical training and is often a challenge for professionals and even more so for clients who are usually non-professionals.

They were therefore looking for tools that could help them to achieve their new goal: to design artifacts that communicate their idea of a building project clearly and effectively to clients – professionals and laymen alike.

2) With the new goal in mind, the actors identify a constraint in the technology.

As a consequence, the architects and engineers saw the 2D artifacts as constraining when they had to communicate them to clients – one of the main purposes of 2D artifacts. While the clients are often accompanied by professional advisors, such as architects and engineers, they still need to be able to interpret and imagine how a building will look like if it is modified, as they might otherwise feel decoupled from the design process, which can result in a loss of trust in the architects and engineers – among other things. For example, if the height of a room is changed from 2 meters to 1.5 meters, it can have consequences for the client's feeling of spaciousness in the room. If trust is lost between the client and the architects, the productivity of the whole project might suffer as every design decision that architects make, even simple ones, needs to be discussed with the client.

To allow for this the 2D artifact was therefore often supplemented with physical models:

> *"…when we started the office, we did a lot of efforts to build physical models because they are also a little bit more tangible. And then, the busier we got* [we did not use] *physical models* [to the same extent] *…"* (Interview – Partner architect).

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[8] For both sections analysing the organizational routines I have inserted these numbered sub-headings. The numbers as well as these sub-headings are equal to the numbers in the figures depicting the imbrication processes of the two identified routines: Figure 17: Illustration of imbrications for the organizational design routine. and Figure 18: Illustration of imbrications in the organizational meeting routine.

The physical models allowed both professionals and non-professionals to imagine the depth of future buildings, but they required a lot of time to produce and adjust.

3) Actors change/modify the technology(ies), leading to a new material agency.

To become more productive, the architects started to incorporate digitally created 3D-rendered images (3D images) into their organizational design routine instead.

This decision was also driven by the recent developments of 3D images which gained increasing favor in the industry. And as they saw themselves as an organization that were not afraid of trying out new technologies, their use of 2D artifacts and physical models was therefore increasingly seen as being in opposition to their goal:

> *"The old school tends to say the pen sketch, the free-hand sketch, is better, because it leaves room for imagination. You don't promise too much* [to colleagues and non-professional users and clients]*. Whereas the new school, if you can say that, if you don't like to visualize it* [e.g. changes to a design] *relatively precisely, the user doesn't know what to comment on. Then it's a little too abstract. Again, this is very black and white, the way I put it. But we are part of this new school, and I constantly hear the older architects telling me 'yeah, it's much better with hand sketch.' Blahblahblah, you know."*
> (Interview – Partner architect).

The architect company saw themselves as being part of the "new school" which made them realize that analogue mediums, such as physical models and pen sketches, were mediums that did not communicate their ideas to their professional colleagues and non-professional users and clients precisely enough. In turn, their current tools were seen as constraining their goal of being able to design artifacts that communicate their idea of a building project clearly and effectively to clients – professionals and laymen alike.

With this new goal and constraint in mind, they extended the current technology by adding a plug-in to their existing 2D CAD software in 2012, while also acquiring more powerful hardware. This new plug-in and hardware made it possible for them to change the way they worked as they could now create 3D images which were much more detailed than what they could produce before. Immersion, in other words, was more likely to happen as these new 3D images were more vivid because the software created more naturalistic 3D images, and the monitors they were shown on had a higher resolution, among other things.

As a consequence, they slowly started to supplement 2D drawings with digitally designed 3D images instead of the physical models. This way, the more immersive technology, the plug-in, and the more powerful hardware solved the constraint as they were able to design artifacts that allowed them to communicate their idea of a building project clearly and effectively to clients.

7.1.2 Imbrication 2 (Material → human)

4) The material agency of the technology provides opportunity for new affordance(s).

In other words, the new plug-in enabled the architects to create more vivid 3D images in an effective way. By first modelling something in 2D, e.g. a plan drawing of a house, and then test it afterwards by rendering it into a 3D image on a PC monitor, they could more easily test 2D designs compared to physical models.

5) The affordance(s) interact(s) with the organizational routine, which might lead to change.

As a result, their internal organizational design routine became more effective because they could adjust and test models more quickly using the 3D images instead of physical models. In other words, the more effective plug-in and its affordance of creating vivid 3D images helped to:

> *"…constantly quality check that what is drawn in 2D actually also looks good spatially. And also, that whatever we do in 2D has a spatial impact. We always want to test that."* (Interview – Partner architect).

This new affordance created a new and more effective ostensive pattern that was retained in the organizational design routine. In fact, it was such a success that the new ostensive pattern largely replaced the old ostensive pattern, which included the physical models they previously used to a wide extent in the architect office.

An important reason for this was that they realized their goal of creating artifacts that allowed them to communicate their idea of a building project clearly and effectively to clients, thus being able to legitimize their use of this new ostensive pattern.

1) Change in the organizational routine creates a new human agency and a new goal.

However, at a later point they realized that the transition away from physical models also had disadvantages. Because the 3D images created were typically shown on a PC monitor, the scale and depth were not always easy to perceive during client meetings. Consequently, they wanted to be able to clearly and effectively communicate their idea to clients, including the scale and depth of a building project.

7.1.3 Imbrication 3 (Human → material)

2) With the new goal in mind, the actors identify a constraint in the technology.

The perception of depth and scale is particularly important to the architects and they therefore saw this new way of designing as constraining. This has to do with the reasoned mentioned above, namely that they want to avoid any misunderstandings when talking with clients as it leads to lower productivity, among other things. Misunderstandings between colleagues could lead to design errors, while misunderstandings between client and architects could, as mentioned, lead to mistrust between the parties. While productivity was an important driver for the organization, the partner architect also at numerous occasions stressed the importance to the architect office of making non-professional clients understand decisions and changes made to the design of their projects:

> *"...I try to take pride in, trying to make projects that my mom and dad can understand. Who are not architects, you know. So, we try to be able to communicate stuff* [to]*...non-professionals."* (Interview – Partner architect).

3) Actors change/modify the technology(ies), leading to a new material agency.

For these reasons, they made the decision to acquire a simple head-mounted display. It was simple because it only consisted of a plastic casing with two lenses, creating a stereoscopic vision to whomever put them on. However, it did not include an inbuilt display. Instead, one could slot in a smartphone, which meant, that it acted as the display into which the user looked.

This would potentially allow them to communicate 2D drawings to their clients in a more intuitive way. Especially owing to the head-mounted display's ability to shut users off from the surrounding environment (inclusiveness), to present a panoramic rather than a limited view, such as the monitors, to the user (surroundingness), and to project the user's head-movements into an immersive VE, it differentiated itself from the previous immersive technology by providing the users with a better sense of scale and depth in the vivid 3D images.

They initially decided to test the head-mounted display on a project they had just won – the design and building of a new church. And for that project, they used the head-mounted display for a meeting with a client. In order to do so, they had to design vivid 3D images that were compatible with the head-mounted display, which meant that four images had to be modelled – one for each direction in which the user looks while wearing the head-mounted display (left, right, up, and down) for that specific spot where he or she is standing in the church. And to make the 3D image vivid and photorealistic, they subsequently had to render each of the four images which typically took around 20 minutes per image – depending on the detail they wanted in the image.

7.1.4 Imbrication 4 (Material → human)

4) The material agency of the technology provides opportunity for new affordance(s).

Accordingly, the head-mounted display's more immersive material agency, provided by the matter and form of the head-mounted display, helped the architects to communicate the depth and scale of vivid 3D images more clearly to clients initially.

5) The affordance(s) interact(s) with the organizational routine, which might lead to change.

However, after testing the head-mounted display during a client meeting, they also changed their internal organizational design routine. That is, when designing and preparing these 3D images, they quickly realized that the head-mounted display enabled them, the architects and engineers, to understand the depth and scale of the current project. Therefore, they started to use head-mounted displays themselves, mostly individually, in order to better understand, test, and adjust their models. For example, when "standing" in the nave of the church, they could quickly see the consequences a change in the number of windows had on the brightness at particular places in the room:

> *"… So, then we…*[had]*…different* [design] *options, like* [for example] *different window compositions…I mean, it was useful...because* [we can see] *the church room…it is obviously more intuitive or nicer to have it* [the model] *in one view* [than looking at four 3D images individually]*, and you can say; 'Ah, yeah, you have these windows there and there, and that kind of works together'."* (Interview – Architect).

As the head-mounted display little by little started to be used internally, it became part of an alternative ostensive pattern which was used when the architects and engineers had to test and experience the scale and depth of their 3D images and models. For example, they needed to test the scale of the altarpiece and whether or not it would affect the lighting in a room during winter and summer. However, as they started to use the head-mounted display and created this new alternative ostensive pattern, they encountered some issues which made it hard to legitimize the use of this alternative ostensive pattern of which the head-mounted display was a part.

1) <u>Change in the organizational routine</u> creates a new <u>human agency</u> and a new goal.

While the architects and engineers started to use the head-mounted display to better understand the scale and depth of projects during their internal organizational design routine, they discovered that the preparations needed for using it were simply too comprehensive. They consequently wanted to be able to communicate their idea, including the scale and depth, of a building project clearly and effectively to each other. And with this new goal in mind, they saw a constraint in the new and more immersive alternative ostensive pattern and wanted to create a new ostensive pattern or simply modify it and thus the new and more immersive technology as well.

7.1.5 Imbrication 5 (Human → material)

2) With the new goal in mind, the actors identify a <u>constraint</u> in the technology.

They realized both that the design of the images was too laborious and that the subsequent rendering of images took too long. To elaborate, at any given day architects and engineers can make many changes to a building project. And while not every change needs to be rendered and then communicated to a colleague or used for client meetings, the amount of time and resources used on designing, communicating, and rendering significant changes adds up.

Thus, while the head-mounted display had improved the understanding of their designs, it was now seen as constraining due to the resources that had to be allocated to the development of 3D images.

3) Actors change/modify the technology(ies), leading to a new material agency.

Especially the plug-in they used to render their images was seen as constraining. To be more precise, after the architects and engineers modelled a 3D image, they had to make it more vivid and photorealistic by rendering it. And the modelling and especially the rendering process constrained the architects and engineers.

Accordingly, they invested in a plug-in that extended their current 2D CAD software which reduced the rendering time of the models significantly due to its ability to utilize GPUs instead of the CPUs of the computers. And because it was much quicker to produce vividly rendered images, it also allowed the architects and engineers to walk and even fly around in vividly rendered models.

However, this new plug-in was not compatible with their current and simple head-mounted display as the display did not support the live models produced by the plug-in – the display relied on the aforementioned static images only, in which one was restrained to standing in a space, not being able to move around in it.

Therefore, they also decided to acquire a more advanced set of head-mounted displays that could be used together with their existing plug-in and desktop computers which had more powerful GPUs.

Consequently, the rendering was done with a click of a button and almost instantaneously:

> *"So, that's a relatively new tool* [new plug-in]*. We've had it for around two months. And it is a plug-in that works with Rhino* [a 3D modelling program] *but also with BIM* [Building Information Modelling] *programs like Revit and SketchUp* [3D modelling programs]*...* [and] *we are communicating with a lot of different people, and it helps with that. Obviously, as architects we are used to read the drawings, because we're trained to do that. So, when we communicate with other architecture offices, they understand the models, but when communicating to clients who are not that used to read 3D models and drawings, it really helps with that. A 2D plan for example. Actually, we* [architects and engineers] *also have problems reading these plans. The really amazing thing about Enscape* [the new plug-in] *is the speed, and the kind of total experience that it gives you. With V-ray* [the old plug-in] *it could take up to 30 minutes to render a picture. With Enscape it only takes around 10-20 seconds and then you can send it off to a client/collaborator/colleague for him or her to see.* (Interview – Architect).

To summarize, by adding a new plug-in to their existing CAD software and by acquiring a compatible head-mounted display, they could now, more quickly than before, check the scale and depth of virtual images and models by walking around or even flying around in them.

7.1.6 Imbrication 6 (Material → human)

4) The material agency of the technology provides opportunity for new affordance(s).

They then decided to use the newly acquired head-mounted display for other projects in addition to the church project. When designing and preparing the artifacts for meetings with clients and users, the architects and engineers soon realized that the head-mounted display also allowed them to discover errors as the new plug-in enabled the architects and engineers to walk and even fly through models due to the plug-in's ability to render designed models instantaneously. Hence, they started to use head-mounted displays themselves, mostly individually, to better understand, test, and adjust their models. For example, when walking around in the church, they could quickly see how a change in the number of windows would affect the lighting in different parts of the room:

> *"That is very useful, because it gives a good result very fast, it's what they call a one-click solution where you have your existing work in either Revit or Rhino* [existing 3D modelling programs]*, and with minimal to no effort you get it in either VR* [in the head-mounted display] *or just, you know, a 3D environment* [shown on a normal display] *where you can walk around. Which is nice, because...when we check…a project, we can now quickly, literally walk through all the rooms and see: 'Hey, that window, that doesn't make sense' in a way that you don't see it in plan* [drawings] *and sections* [drawings]*..., or it's more work in, ehm…you know in your mind to combine the elevation* [drawing]*, you know, with the plan* [drawing] *and then see the room, where it's now in VR where you just literally walk through and you say: 'Hmm, maybe we should move that window, maybe half a meter in.' – So as a design tool...it's very good, because it's so fast."* (Interview – Architect).

5) The affordance(s) interact(s) with the organizational routine, which might lead to change.

This also resulted in improving the efficiency of communicating design changes between the partner architects and the other employees. This is because some of the partner architects are not necessarily involved in any given project on a daily basis. However, because of their role as partner architects, they still needed to get regular updates as they often attended meetings with clients. The head-mounted display together with the new plug-in helped them to quickly get updates on the progress of the projects:

> *"The partner's function is not to sit and model the project and execute it, which is why I am employed* [the engineer]*...So, they can suddenly relate to the model in a completely different way, and as a designer, I can quickly convey some geometry to them. As they can sit and look at it and analyze...without me having to stop my work in front of the computer. So, I can send a model to them. Or, if they have access to the model, they can go in and just go for a walk."* (Interview – Engineer).

The head-mounted displays and the new plug-in helped the architects and engineers to experience the design in a quick and efficient manner as it allowed them to stand, walk, and fly around in an immersive VE. Consequently, they could now discover errors or perform different kinds of tests in terms of lighting and scale to improve their design, which allowed them to realize their goal of communicating their idea of a building project, including its scale and depth, clearly and effectively to each other.

In other words, an alternative ostensive pattern of the organizational design routine was created due to the affordances that the plug-in and a new and more advanced head-mounted display provided to their users.

While using the head-mounted display, however, the architects and engineers were shut off from the surrounding environment, due to its materiality – the form and matter of the plastic casing. In this manner, the use of the head-mounted display made the organizational design routine more individualized than it was before. Consequently, the alternative ostensive pattern of which these more immersive technologies were a part was put into question as they could not use the new ostensive pattern to refer to, and to make sense of their current actions together with colleagues – but only individually, which I will elaborate on in the next imbrication.

1) *Change in the organizational routine creates a new <u>human agency</u> and a new goal.*

In the company, the internal organizational design routine was highly collaborative. Other professionals needed to be involved, such as engineers who had to participate actively in the technical aspects during the design of models, or partner architects who needed to be updated on the designs. Consequently, the architects and engineers at the company sought to make their new ostensive pattern, which involved the new and more immersive technologies, more collaborative while maintaining the benefits of the more immersive technologies. In short, they wanted to communicate their idea, including the depth and scale, of a building project clearly and effectively to each other while also being able to discover errors.

7.1.7 Imbrication 7 (Human → material)

2) With the new goal in mind, the actors identify a constraint in the technology.

With this new goal in mind, the employees at the company quickly discovered that while the head-mounted display was useful for understanding something individually, it constrained them in discussions and negotiations with their colleagues, as the materiality of the head-mounted display shut them off, physically, from the surrounding environment. Hence the defining immersive feature of the head-mounted display, its inclusiveness, was now, paradoxically, seen as a constraint. During my observations of their work, this paradox was directly observed.

For example, at one point, three architects were standing around a computer connected to a head-mounted display and controllers that the user of it could use. Then one of the architects put on the head-mounted display, took the controllers, and then started to walk around in the model while the two others were looking at the monitor that showed what the architect with the head-mounted display was looking at when walking around. The ones that were not using the head-mounted display were discussing the layout of the building, the look of the model, the material of the surfaces etc. by looking, referring, and pointing to the PC monitor. At one point, one of the architects, the project architect, wanted his colleague with the head-mounted display to look in another direction. Initially he tried to say 'look over there', but the architect that was wearing the head-mounted display did not understand where to look. After trying to explain in which direction the user of the head-mounted display should face, the architect turned his colleague in the direction he wanted him to look by grabbing the architect that was wearing the head-mounted display by his shoulders to indicate in which direction he should move. Then he laughed and remarked: *"He is [like] a mouse…"*. Once they had finished commenting on the model, the architect took off the head-mounted display, and he and the architect partner went away from the head-mounted display and the computer. The architect that remained at the computer with the head-mounted display put it on himself and walked around to check up on some other design details for around 1 or 2 minutes.

The example shows that the materiality, the form and matter of it, cut off the user of the head-mounted display from his colleagues. This made it hard for them to communicate and collaborate with each other even though they could see what the user of the head-mounted display was seeing on a PC monitor. However, it also illustrates that it can help architects to understand a design better if used in situations where collaboration with other architects is not necessary as the remaining architect checked out some additional details after the others had left.

However, another important point also is that when designing both individually and together with others, architects often need to consult other non-digital artifacts, which is not possible when they put on their head-mounted display as the material properties of the device shuts them off from their surrounding environment.

For example, at one point during my observations, I observed an architect that was working on a 3D model of a building project on her desktop computer. During her work she was doing several things at once. On the computer, multiple programs were running: Rhinoceros, AutoCAD, and Adobe Illustrator (BIM programs). She predominantly used AutoCAD for the task she was currently doing, quality assurance of a 3D model.

In addition to this, she had several bundles of paper lying around on her desk, which she used simultaneously when she worked in AutoCAD. The pieces of paper were mainly showing 2D drawings, such as elevation and plan drawings. While working on the computer she sometimes consulted the drawings to get an overview or to jot down notes on them where she had found errors or collisions in the digital model. In addition to that, she also had material samples spread around on her desk e.g. a carpet sample.

This example illustrates that because the architects and engineers often needed to collaborate and consult non-digital models, they then started to see the head-mounted display as something that constrained their actions in specific situations.

3) *Actors <u>change/modify the technology(ies),</u> leading to a <u>new material agency</u>.*

Therefore, they started to model and render 3D models using the new plug-in, but instead of putting on the head-mounted display they simply viewed the rendered model on a traditional monitor. This in turn allowed them to discover errors while also being able to collaborate with their colleagues and consult non-digital artifacts during the design process.

This way of using 3D models generated by the new plug-in on their PC monitor started to become the preferred way of gaining a better understanding of the 3D models in a collaborative manner. Consequently, the head-mounted display was only used in situations where they needed to understand something individually. The circumvention of the head-mounted display helped them to resolve the constraint that the materiality of the head-mounted display created, its matter and form.

7.1.8 Imbrication 8 (Material → human)

4) The material agency of the technology provides opportunity for new affordance(s).

In some of the previous imbrications, head-mounted displays enabled a better understanding of depth and scale. However, these affordances were most beneficial during individual use while constraining discussions with colleagues and the use of other non-digital artifacts. Therefore, they started to use the plug-in less with head-mounted displays and more together with traditional displays whose materiality did not hinder interaction with colleagues or non-digital artifacts.

5) The affordance(s) interact(s) with the organizational routine, which might lead to change.

This in turn changed the organizational routine by helping communication across disciplines – between engineers and architects especially, for example in the later stages of the design process when engineers are translating architects' conceptual drawings into technical drawings. At this stage, the ability to create detailed 3D models of 2D drawings, which the architects could walk through either alone or together with an engineer, reduced the need for architects and engineers to rely on their own interpretation of 2D drawings. Instead, they could talk and discuss while referring to a common interpretation of the 2D model, the rendered 3D model created by the plug-in, in turn reducing misunderstandings. For example, at one point during my observations, three architects are sitting at the desktop computer and one of them walks through the 3D model of the church using the plug-in, Enscape (the new plug-in). They also use other artifacts to communicate, argue, and discuss the pros and cons of design ideas: paper drawings, both 2D plan drawings and 3D renderings, and the computer monitor to communicate, discuss, and edit designs.

Later, they also used physical materials (e.g. wood samples). At one instance, they discussed whether or not to use some lamps in the ceiling instead of the existing types of lamps. At other times they discussed the different materials that could or could not work with regard to the holistic composition of the nave of the church, but also if some materials would be too expensive.

This illustrates the collaborative nature of the organizational design routine and how, by being able to refer to the same 3D model and non-digital artifacts, they can, among other things, reduce misunderstandings and eventually realize their goal. More importantly, it also showed that when all of the meeting participants could refer to something on the PC monitor, while walking through the model of the church, they could discover errors more easily as both the user walking through the 3D model and his or her colleagues could view the same model, balancing the conversation between them.

So, when collaborating, they did not use the head-mounted display very often as the materiality, its inclusiveness, shut them off from their colleagues and other non-digital artifacts. However, when testing, getting updates on changes, and perceiving scale, they enrolled the head-mounted displays in the organizational design routine – but only when they had to understand aspects of the 3D model individually, for example when partner architects needed to be updated on design changes or when they needed to perceive scale and depth issues. That is, the alternative ostensive pattern in which the head-mounted display was enrolled was predominantly performed when architects and engineers had to understand the depth and scale of 3D models individually.

However, because the organizational design routine was highly collaborative, often requiring discussions and negotiations with colleagues, it was especially the new plug-in's ability to render the 3D models instantaneously, thus enabling users to walk or fly through their models, that changed the existing ostensive pattern of the organizational design routine.

As they used these ostensive patterns at different times, the materiality of the head-mounted display could be circumvented, due to the flexibility of both the technology and the human actors involved in the organizational design routine. This was due especially to the plug-in's compatibility with the display and to the actors' technical competences, which allowed them to appropriate the technology in a way that suited their goals. In this manner, the ostensive patterns could be used by the actors as a guide for their future performances and as a way to account for and refer to past and current performances, which aligns with their goals.

In short, by using different ostensive patterns, with or without head-mounted displays enrolled in them, they realized their goal of clearly and effectively communicating their idea of a building project, including the depth and scale, to each other while also being able to discover errors.

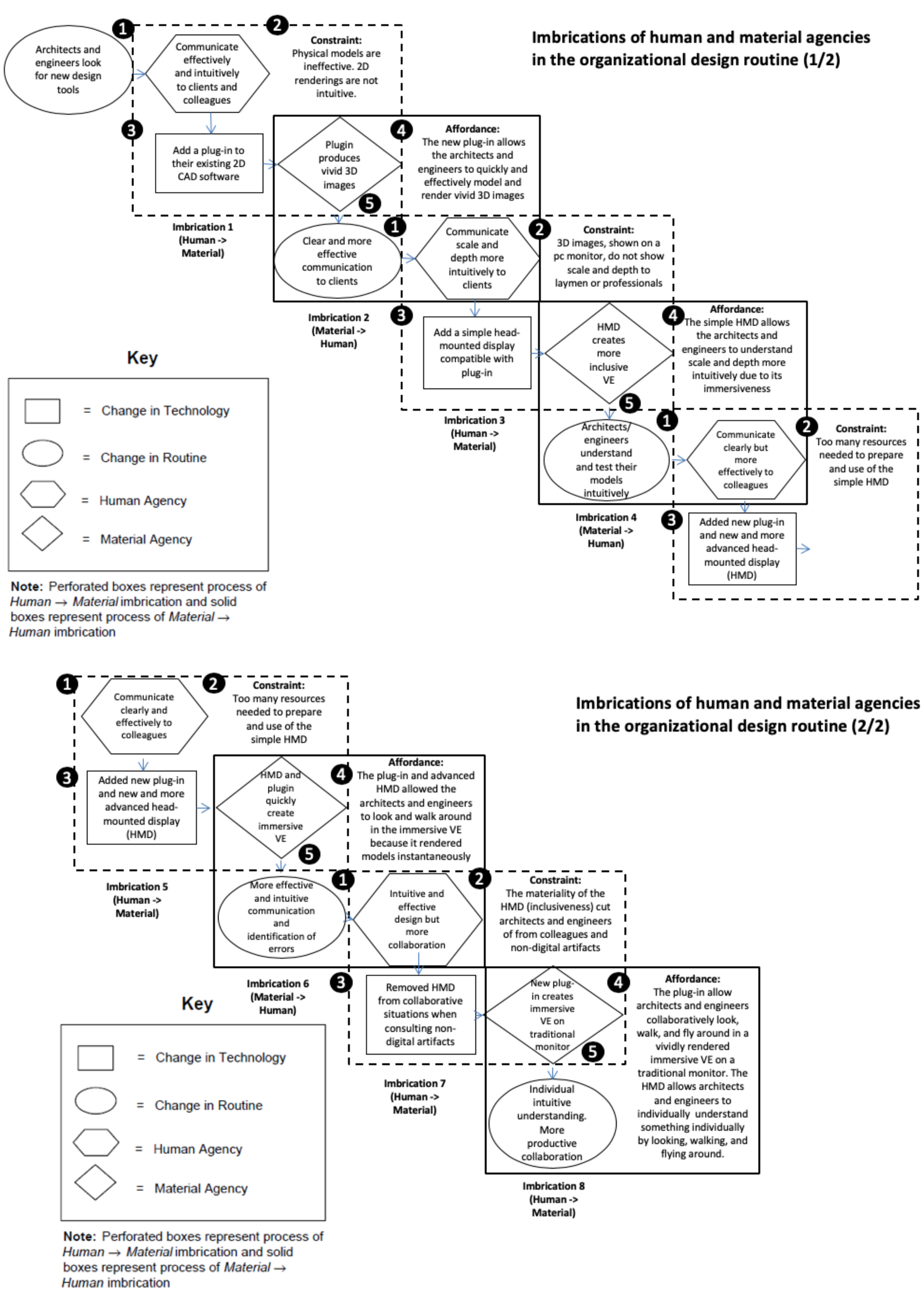

Figure 17: Illustration of imbrications for the organizational design routine.

7.2 The organizational meeting routine

The overall purpose of the external organizational routine is to show the status of the project to the clients and/or to get feedback from the clients or the future users of the building so that the architects/engineers can move forward with the project. Sometimes, the client(s) and the user(s) are the same. For example, in a project of building a new church, the pastor provided information where to place the baptismal font, and he also had an important say in relation to the funding of the project, e.g., how much money was allocated to the design of the church.

The first step of the organizational routine is when the architect/engineer presents the agenda and the topics that need to be discussed with the client/user. For example, a topic could be the diverse types of wall material for the interior of the church room. The presentation is done by the project architect while other representatives from the office contribute when necessary. In the next step, the clients provide feedback on the presentation. Subsequently, feedback and other topics are discussed. The meeting ends when the time runs out or when the architect/engineer receives enough feedback to go on with the project.

From this description of the ostensive pattern of the organizational routine, I will identify, in the following section, the imbrications of the employees and the technologies that occur over time. Through these imbrications, I highlight the performative variations that include head-mounted displays in the organizational meeting routine. With that I aim to understand whether or not these variations will create a new ostensive pattern or modify or maintain existing ostensive patterns of the organizational routine. This potentially new or modified ostensive pattern can be used for the employees to either guide future performances or account for past performances, or be used as a reference to current performances and thus become a viable alternative ostensive pattern.

In this way, I aim to shed light on how head-mounted displays, including the technical infrastructure it relies on, imbricate with organizational routines.

7.2.1 Imbrication 1 (Human → material)

1) Change in the organizational routine creates a new <u>*human agency*</u> *and a new goal*[9].

Traditionally, architects in the company relied on 2D drawings produced by the 2D CAD technology and physical models to get focused and relevant feedback from clients and users

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[9] The number and the headline correspond to the same number in the illustrations that depict the imbrications of human and material agency. These illustrations are located at the end of each analysis of the two organizational routines.

during meetings. When using physical models, the client and the user could imagine how a future design would look like because they provided 3-dimensionality, although in rather little detail as the models were often scaled-down versions of a room or a building. This was because they were mostly intended to communicate dimensions and scale. For example, to show the height of a clock tower relative to the rest of a church building.

2) With the new goal in mind, the actors identify a <u>constraint</u> in the technology.

However, the artifacts did not allow users and clients to provide rich feedback, as it was difficult for them to interpret especially the 2D drawings, but also the physical models which were made in the early stages of a project and which were often quite abstract:

> *"…like when you show them a white volume physical model made in foam, and it's at a scale that they might not understand, or it doesn't have the detail that they want to see…"* (Interview – Architect).

The feedback from the clients was consequently not relevant because it was difficult for them to understand scale and depth issues. In addition, these physical models were often very laborious to craft and change.

As digital technology slowly developed to become more immersive, e.g. vivid and photorealistic 3D images, the architects and engineers started to perceive the technology, the physical models especially, as a constraining factor. That is, their current tools, and especially the physical models, were seen as constraining because they wanted to be able to get focused and relevant feedback from the meeting participants in an effective manner in order for them to move forward with the project.

3) Actors <u>change/modify the technology(ies),</u> leading to a <u>new material agency</u>.

To overcome this constraint, the company decided to change the 2D CAD program they use to create 2D drawings, by extending it with a plug-in. This extension allowed the architects and engineers to develop more immersive 3D images on the basis of the renderings of their 2D drawings. The 3D images helped them to create more vivid and detailed visions of their clients' projects at an earlier stage of the project.

In this manner, the ability to create more immersive 3D images facilitated a more specific dialogue between the professionals and their clients, thus resolving the constraint that the physical models posed.

7.2.2 Imbrication 2 (Material → human)

4) The material agency of the technology provides opportunity for new affordance(s).

Similar to the internal organizational routine, the use of a new plug-in for the existing software enabled them to model immersive 3D still images. As mentioned, the primary reason for using these images for clients and users was to get more precise and detailed feedback from them on future buildings as 2D drawings and physical models were too abstract. These 3D images were often shown to clients and users either on printouts or on a computer monitor during meetings, for example as part of a PowerPoint presentation. The 3D images were more immersive and could also be produced more efficiently. That is, in contrast to the physical models, they were less abstract and offered some sense of scale and depth by modelling for example humans next to a building, while also being more efficiently produced. This helped clients and users to become more involved during meetings:

> *"...we had brought these 3D renderings with us* [3D images printed on paper]*. It certainly made it easier for them to imagine* [the project]*. Because it was hard* [for them] *to imagine the project in 2D...*[by showing] *the plan drawings...the elevation drawings...and the section drawings* [referring to 2D drawings that show the project from above, from the side, and a cut-through of the building]*. So, when they started to see the* [3D] *renderings...something clicked* [for the users]: *'Oh, well, does it look like that!' So, they* [the 3D renderings] *were a really good translating factor."* (Interview – Architect).

As they started to do more 3D images, and as they got better hardware, it took less time to render the images.

5) The affordance(s) interact(s) with the organizational routine, which might lead to change.

Consequently, they replaced physical models little by little, to the extent that they were rarely used at the meetings with clients and users as the plug-in allowed them to achieve their goal of getting focused and relevant feedback from the meeting participants in an effective manner.

And because it allowed them to achieve their intended goal, once the plug-in was used in the organizational meeting routine, the plug-in, as well as the immersive 3D images it could produce, created an alternative ostensive pattern which became an integral part of the organizational routine.

An important reason for the success of the plug-in was that the digital materiality of both the existing software and the plug-in allowed the workers to manipulate with it in a relatively straightforward way. That is, they could with relative ease integrate the plug-in into the existing infrastructure created by previous imbrications (existing software and hardware and existing organizational routines). Due to these factors, the ostensive pattern of actions that the plug-in afforded, supported their goal. Consequently, the meeting participants could use this new pattern of actions as: a reliable guide for their future performances, as a way to explain and legitimize past actions to the other actors involved, and as a way to make sense of their current performances because the affordances, enabled by the plug-in, supported their goals.

1) Change in the organizational routine creates a new <u>human agency</u> and a new goal.

As the more immersive 3D images replaced physical models, they discovered some issues with the immersive 3D images. That is, while the 3D images provided users with a more vivid and detailed vision of future building projects, the way users perceived scale and depth sometimes hindered communication between meeting participants. In particular, clients and users had to interpret and imagine the scale and depth of the designs that the 3D images portrayed. For example, the size of a window relative to the wall can be difficult for non-professionals to assess. And while the architects and engineers often included other items in the immersive 3D images to better show the scale and depth of building projects, for example by placing a human-sized figure next to a door, misunderstandings could arise between the meeting participants. On the other hand, the physical models, while often abstract, were physical and could thus provide a more intuitive form of scale and depth to users and clients but were inefficient, and hard to change.

As a result, the architects and engineers wanted to acquire an alternative tool that could provide a more intuitive form of understanding scale and depth to the often non-professional users and clients that were participating in the meetings.

7.2.3 Imbrication 3 (Human → material)

2) With the new goal in mind, the actors identify a <u>constraint</u> in the technology.

Around 2014, they realized that a simple version of a head-mounted display could potentially help them to achieve their goal: to provide clients and users with an intuitive understanding of scale and depth.

3) Actors <u>change/modify the technology(ies),</u> leading to a <u>new material agency</u>.

In 2014, when they started to experiment with head-mounted displays, they had just entered the mainstream market, so the head-mounted displays that were accessible to the architect office were still rather simple. The head-mounted displays were simple in the sense that they only consisted of a plastic casing with two lenses and a head-strap – but they did not have an inbuilt display. Instead, a smartphone could be slotted into the casing and act as the display. The smartphone could then show a panoramic view by using 3D images stitched together and created by the aforementioned CAD software and plug-in they were already using in the organizational design and meeting routine.

By looking at these 3D images wearing the head-mounted display, the user got the illusion of standing in a VE and a greater sense of depth and scale – the experience became more immersive compared to the 3D images that they previously showed on a screen or on paper to the meeting participants. This is due to the head-mounted display's ability to enable users to look at a panoramic view through stereoscopic lenses in a natural manner (proprioceptive matching), as well as its ability to provide a more inclusive experience as the users were shut off from the surrounding environment.

The head-mounted display was then enrolled in the performance of organizational meeting routine:

> *"...when* [the clients were standing] *in the middle of the church room…and looked around…* [they] *were very happy with that. 'Cause it gives a very different...it's already a very different spatial exterior experience than a still image…I mean, this is obviously* [just] *a rendering* [3D images] *from the inside* [of the church room]*, but by just being able to look around, you get a better understanding of the true size of the space. More than in a still image. Despite obviously being the same space…"* (Interview – Architect).

In short, the head-mounted display seemed especially useful during meetings where the clients and users did not have any experience with interpreting 2D drawings, 3D images, or other architectural artifacts.

7.2.4 Imbrication 4 (Material → human)

4) The material agency of the technology provides opportunity for new affordance(s).

The material agency of the head-mounted display facilitated its users with a more immersive and thus intuitive experience as it allowed them to look around in a natural manner and be less aware of their surrounding environment when the display was used during meetings. Consequently, the organizational meeting routine started to change.

5) The affordance(s) interact(s) with the organizational routine, which might lead to change.

In particular, the more immersive material agency of the head-mounted display, as well as the existing infrastructure it was conditioned of, allowed the actors involved in the existing organizational meeting routine to create an alternative ostensive pattern of which the head-mounted display was part of.

In this way, their goal of providing clients and users with an intuitive understanding of scale and depth had been achieved.

This new ostensive pattern, of which the head-mounted display was a part, became an alternative pattern to other already existing ostensive patterns (e.g. the display of 2D drawings on paper and 3D images on regular displays). However, they realized that this new way of making meeting participants understand the scale and depth of 3D images shared a trait with the physical models – it was inefficient. Because of this drawback, the architects and engineers that used this ostensive pattern as a guide for their performances had a hard time legitimizing the continued use of the alternative ostensive pattern of which the head-mounted display was a part. Consequently, the actors sought for new ways to change the technology and the infrastructure of existing organizational routines and technologies upon which the head-mounted display relied on.

1) Change in the organizational routine creates a new human agency and a new goal.

As indicated in the aforementioned imbrication, the inefficiency of the head-mounted display made the actors that had utilized it for meetings question its usefulness. That is, while it had helped them to achieve their initial goal of letting especially non-professionals get an intuitive understanding of scale and depth, the resources that had to be allocated to prepare the head-mounted display for the meetings, the modelling, and the rendering (adding details) of four 3D images to create a panoramic view, were not seen as being worth the effort. Consequently, a new human agency was initiated by the architects and engineers which sought a way to make meeting participants understand the scale and depth of projects intuitively but effectively, in turn allowing them to move the project forward.

7.2.5 Imbrication 5 (Human → material)

2) With the new goal in mind, the actors identify a constraint in the technology.

The aforementioned head-mounted display was only used in two projects as they perceived the head-mounted display as constraining due to the inflexibility of its materiality. For example, it was programmed to work with four separate images which had to be modelled and rendered individually. In addition, the former infrastructure of previously laid out imbrications of organizational routines and technologies conditioned the head-mounted display in an inefficient way. That is, because it was dependent on the existing CAD software and plug-ins they used in the organizational design routine, it became an inefficient process to prepare the head-mounted display for the meetings. As a consequence, the ostensive pattern of which the head-mounted display was a part, was not maintained and it was largely not used.

3) Actors change/modify the technology(ies), leading to a new material agency.

At a later point, in 2017, the architects decided to acquire a new plug-in which rendered 3D images much faster due to its ability to utilize the GPU instead of the CPU, which the old plugin relied on. In turn the new plug-in allows clients and users to walk through live models instead of looking at still 3D images.

An important criterion for this new plug-in was that its digital materiality was flexible enough to be compatible with the existing CAD software used in the organizational design routine. However, because the new plug-in required a powerful GPU to render models on the fly while the user was walking through it, the smartphone that acted as the display was not compatible with the new plug-in. Consequently, the simple head-mounted display was neglected and rarely used going forward. The old plug-in and the 3D still image it could model and render, though, remained part of both organizational routines. As a result, both plug-ins were now used together with a traditional display, a monitor, instead of the head-mounted display.

Initially, they used the new plug-in for letting clients and users walk through the model of for instance a building, by themselves, while looking at the monitor. This allowed the architects and engineers could start a dialogue with the clients or get domain-specific knowledge from users as they were exploring the 3D model. This in turn generated feedback which helped them discover more errors and/or move the project forward.

7.2.6 Imbrication 6 (Material → human)

4) The material agency of the technology provides opportunity for new affordance(s).

The material agency of the new plug-in thus resulted in the meeting participants being able to not only look but also walk around. This in turn helped the clients and users to experience the scale and depth of the 3D models of future projects.

As a result, the organizational meeting routine became more interactive as they started to understand the designs at an earlier stage of the building process. The new plug-in was for example initially used for a second church project, where the journey was especially important for the architecture of the building.

In the following quote, the architect walks through the model himself to illustrate a point:

> *" ...then of course it's also good for clients to see, hey, this is the experience we* [the architects] *want to give you, especially in a project like this, where the journey is so important. 'Cause it's not about, you know, being on the top* [of the church]*, it's really about how you go to the top…the way of going to the top is equally, if not more, important than* [being at the top of the church]*...Or like the things you pass...'Cause maybe some people would just stop here* [the architect stops walking] *and don't go further. So, it's not about…about one spot, it's really about the whole journey. So...in this particular case, Enscape* [the new plug-in] *is even nicer. Then you can see…how it* [the architecture] *changes from one level to the next."* (Interview – Architect).

Because the plug-in allows clients and users to walk through a model, they can potentially experience projects such as the church project for which walking is an important part of the architecture. The walking around also to some degree helped the meeting participants to understand the scale and depth of 3D models, as they were embodied in an avatar the height of a human, in the VE, while also being able to move around. Together, the enablement of walking around to explore the 3D models and the embodiment helped them to become more immersed and thus to understand the scale and depth of projects more effectively, in turn allowing the architects and engineers to move the project forward.

5) The affordance(s) interact(s) with the organizational routine, which might lead to change.

Consequently, the ostensive pattern in which the new plug-in was involved changed the existing ostensive pattern by becoming a viable alternative to existing tools, such as 2D plan drawings printed on paper or 3D-rendered images shown on monitors.

The alternative ostensive pattern that the new plug-in was part of kept being maintained by the actors' performances due to the efficiency of the new plug-in, as efficiency was part of their initial goal.

In other words, the actors that used this new ostensive pattern thought of the plug-in as relevant because it did not constrain their goals. And because of this, they could use this ostensive pattern as a guide for what actions they should take in the future, to help them prioritize how they should perform their current actions, and lastly, to legitimize their past actions to others as it matched, at least partly, with their current goal of being effective.

While the architects and engineers managed to create a more efficient organizational design routine by using the new plug-in as well as creating a more interactive dialogue with meeting participants, they had lost another aspect by disregarding the head-mounted display – the intuitive understanding of scale and depth which immersion provides to users.

However, as will be explained in the following section, despite of this drawback, the new plug-in kept being part of the ostensive pattern of the organizational meeting routine due to the flexibility of its digital materiality which could incorporate both past and future imbrications and their conditioning infrastructure.

1) *Change in the organizational routine creates a new human agency and a new goal.*

As the architects moved away from using the simple head-mounted display during meetings, they experienced some issues – issues that they had experienced before. In particular, they continued to experience challenges with clients' and users' understanding of the scale, depth, and space of the buildings they had modelled.

So, now that they had an effective way to produce 3D models, they also wanted to be able to make the clients and users understand the depth and scale of 3D models in an intuitive way, to facilitate communication between the meeting participants.

7.2.7 Imbrication 7 (Human → material)

2) With the new goal in mind, the actors identify a constraint in the technology.

This made the architects and engineers realize that showing 3D models on a PC monitor to clients and users was a barrier for them to achieve their goal.

3) Actors change/modify the technology(ies), leading to a new material agency.

To overcome this constraint, they extended the plug-in with a new type of head-mounted display. This head-mounted display was connected with wires to a dedicated external computer as it depended on the computer and the plug-in to render the 3D models. The new head-mounted display could also allow users to walk and look around in the 3D model by using their body as four sensors were continually registering the users body movements. In practice, however, the users rarely walked around using their body but instead used a joystick, due to space constraints. As hinted, to accomplishes this more immersive experience, the head-mounted display also relied on the new plug-in, which made the architects' the and engineers' new or existing models compatible with it. Together, these features of the head-mounted display could potentially enhance the feeling of immersion as the display, in comparison with a traditional monitor, increased the immersive factors of inclusion (the extent to which the surrounding environment is shut off), due to the materiality of the head-mounted display, and surroundingness (the extent to which the field of view is covered), due to its ability to show a panoramic view of the 3D model – and lastly because the sensors of the head-mounted display the meeting participants' movements (proprioceptive matching).

In this manner, the agency of the architects and engineers, the flexible materiality of the new plug-in, and the head-mounted display made it possible to enroll the immersive head-mounted display into the organizational meeting routine. And more importantly, these factors also made it possible to make it fit into the existing infrastructure of previous imbrications of technology (e.g. the CAD software, the computers) and organizational routines on which this imbrication was dependent.

Due to the new material agency, made possible by the newly introduced technologies, clients and users could explore and discover the models themselves. In this way, users could experience the buildings in real dimensions and have the psychological experience of being there – just like the first attempt with the simpler head-mounted display enabled its users to have. Consequently, the potential for experiencing the 3D model in a more immersive manner was more likely.

7.2.8 Imbrication 8 (Material → human)

4) The material agency of the technology provides opportunity for new affordance(s).

Indeed, the head-mounted display enabled the users to become more immersed in the 3D model. By using controllers and their body movements when wearing the head-mounted display, clients and users could look and walk around in the 3D model in a more natural manner, which facilitated a more intuitive understanding of the building in question. In the following quote, a head-mounted display is used, for example, to convince a client of some changes that had to be made on a project:

> *"Once* [I used head-mounted displays]*…when we were convincing a client to reduce the height of a ceiling in a room…the difference in height* [before and after the changes] *was not so extreme* [but the client was not convinced]. [For that situation] *it was very convenient to be able to create* [a virtual model of] *this room, with materials and so on. So* [when they put on the head-mounted display, they could see that the changes to the ceiling of] *the room did not scare them. But they got an impression of the heights and the light. And they were able to see 'Okay, that's pretty nice'. It can be a bit difficult to sell* [convince] *something like that off a 2D drawing, it's all flat."* (Interview – Architect).

In the relation between the client and her agency, and between the materiality and the agency of the head-mounted display, new affordances became available to the client. These affordances helped her and the architect to intuitively understand that the new version of a room, with a lowered ceiling, did not affect the room in a negative way, e.g. by reducing the intake of light in the room.

5) The affordance(s) interact(s) with the organizational routine, which might lead to change.

In this situation, and in other instances as well, the more intuitive understanding of the scale and depth of a room helped the architects and engineers to move the project forward more quickly.

At the same time, it also helped the architects quickly demonstrate their commitment to the project and establish trust with their clients. To be more precise, the head-mounted display and the plug-in enable the architects to communicate design changes and decisions to clients, and in a more intuitive manner than before. This in turn helps the architects and engineers to make the design process more transparent and easier to understand for especially non-professional clients. And by being able to do so, they avoid losing their clients' trust because the clients can experience themselves that their concerns are recognized. An interviewee explained trust as an important aspect:

> *"...it's been my experience that as soon as there is trust in the architect, and as soon as they* [clients and users] *understand that you are on their side and that you want to create something really great...* [communication becomes easier]*."* (Interview – Architect).

The agency of the meeting participants and the head-mounted display, as well as its materiality, collectively changed the organizational meeting routine. Because the head-mounted display, and the technological infrastructure it relied on, aided the clients and users to achieve a more intuitive understanding of 3D models, they could more easily get feedback from them without losing their trust. Together, this helped them to achieve their goal, which made them maintain this new alternative ostensive pattern that the head-mounted display was part of.

As in the previous imbrications, an important factor for the success of the roll-out of a more immersive head-mounted display was the architects' and the engineers' goal and ability to integrate it into the infrastructure laid out by previous imbrications. However, equally important was the flexibility of the digital and physical materiality of the plug-in and the head-mounted display, respectively, and their agencies. Together these aspects contributed to the architects and engineers achieving their goal of making the clients and users understand the depth and scale of 3D models in an intuitive way. And because this alternative ostensive pattern, of which the head-mounted display was a part, was on pair with their goals, the actors in the organizational routine could use the ostensive pattern to make sense of their current performances during meetings, and help them account for and legitimize their past actions to colleagues, and lastly, they could use the new ostensive pattern as a guide for the performances they ought to do during meetings.

Overall, the head-mounted display made the organizational routine more interactive, as clients and users were increasingly involved and generated more feedback during the meetings. However, as involvement and feedback increase, negotiations are intensified until a final decision or agreement is made. Therefore, as architects gained experience from observing the clients and users using the head-mounted display, they identified some significant constraints.

1) Change in the organizational routine creates a new human agency and a new goal.

As clients and users gained a better understanding of the designs and provided more feedback, the architects' primary objective was to negotiate with the clients to reach a decision during a meeting. While the head-mounted display allowed clients to intuitively understand the scale and depth of 3D models, it also constrained collaboration and negotiation activities.

The clients and users who had the display mounted to their head, covering their eyes and at times their ears, were effectively shut off from the surrounding environment. Consequently, the clients and users were also shut off from the other meeting attendees as well as the other physical artifacts present during meetings. Thus, while the materiality of the head-mounted display effectively immersed its users and helped them to intuitively understand the design or the changes that were made, they could not refer to the other artifacts in the room nor communicate with the other people present as their sight and, at times, their audio senses were shut off. This made it difficult for the architects and engineers to understand specific problems that the clients and users pointed out, even if the architects and engineers were following the user's view of the head-mounted display on a PC monitor, as the professionals could not experience scale and depth in the same intuitive way as the immersed user did. For example, a pastor might feel that the baptismal font should be of a certain height because it feels right in proportion to her line of sight and virtual body as she is standing next to it. However, the architects cannot participate in the dialogue as they have to imagine the scale of the baptismal font. In addition, the pastor cannot see any of the physical artifacts lying around on the table either, nor is she able to interpret the body language of the meeting participants in the room. Together, these factors could in turn lead to misunderstandings between the pastor and the architect and eventually a loss of trust or construction errors, for example. Both of which can lead to delays to the overall project.

Further, when clients and users were using the head-mounted display, the architects and engineers could not guide them or point out where the clients and users should focus. Without guidance, the feedback was often not relevant at that specific time of the project or was simply just irrelevant to the project as a whole. On the one hand, while the architects and engineers could simply disregard this feedback, the feedback might, in time, also lead to a loss in trust between the two parties, potentially jeopardizing their collaboration and in the end the project as a whole. On the other hand, making 3D models of every design suggestion that clients come up with requires much work which frustrated the architects and engineers:

> *"And then the problem is that…they* [the clients and users]*…think there's just a magic button for everything…the danger of these tools, in a way, is that once you've shown something like Enscape* [the immersive VE]*, where it's very flashy and very pretty…*[then] *very quickly, an expectation that that is the norm…without really understanding the work involved in placing all of this information together and filtering through it."* (Interview – Architect).

In short, the architects and engineers experienced that during meetings, they were sometimes forced to accept and incorporate too many of these irrelevant changes that clients and users identified while exploring 3D models by themselves, to avoid making their collaboration with clients and users mistrustful. However, as a consequence they would often have a lot of extra and irrelevant design work in their design routine, leading to a less productive organizational routine internally.

Therefore, they sought after a way to change the technology so they could deal with these new constraints. That is, they pursued a new goal where the following criteria should be satisfied. First, they wanted to change the technology in a way so that all the meeting participants would be able to get the same immersive experience to avoid misunderstandings. Second and at the same time, the technology should allow layman clients and users especially to be able to experience the 3D model intuitively. The third criterion was that the aforementioned criteria also had to be balanced with the ability, for any user of the head-mounted displays, to refer to the other physical artifacts during meetings, the 2D plan drawings for example, which could be just as important as the 3D models. In addition, and at the same time, the new technology should allow them to interact with their colleagues. And lastly, the architects and engineers needed to be able to guide the clients and users in order to strike the right balance between relevant and irrelevant feedback. However, at the same time, they also looked for a way to preserve the immersive aspects of the head-mounted displays, their inclusiveness, which they had lost in the previous imbrications while preserving the ability which helped them to get focused and relevant feedback from clients and users.

In short, they wanted to maintain the intuitive understanding between meeting participants while the user of the head-mounted display should be able to interact with the surrounding environment so the architects could guide him or her to get relevant feedback.

7.2.9 Imbrication 9 (Human → material)

2) With the new goal in mind, the actors identify a constraint in the technology.

For these reasons, the architects and engineers therefore saw the head-mounted display as something that constrained their intentions and what they wanted to achieve with a more immersive technology such as the head-mounted display. That is, due to the inflexibility of the physical materiality of the head-mounted display, it was hard for the actors in the organizational meeting routine to change the technology. And, if they had the technical know-how to change this important defining feature of the head-mounted display, its inclusiveness facilitated by the materiality of the casing, they could potentially lose its ability to make layman clients and users understand the model in an intuitive way and hence the ability to get focused and relevant feedback from them. As a consequence, the architects and engineers were looking for ways to change the head-mounted display. To be more precise, the architects and engineers were looking for ways to change how and when they used it due to the inflexibility of the head-mounted display.

3) Actors change/modify the technology(ies), leading to a new material agency.

As they became aware of these constraints they started to use the head-mounted display more mindfully during meetings with clients and users, while to a larger degree making use of a traditional PC monitor only. Thus, instead of using the two types of displays together, the architects or engineers, at specific times during the meeting, looked and walked around in the 3D models using a traditional PC display only, while at other times, they introduced the head-mounted display together with or without the traditional PC monitor. In other words, instead of using the two types of display in parallel, they started to use them in a more sequential manner, at different times during the organizational routine.

In this fashion, the architects and engineers could potentially solve the constraint they had run into. In particular, by using the head-mounted display and the PC monitor mindfully and at strategic points in time, they facilitated an intuitive understanding between meeting participants while the user of the head-mounted display was able to interact with the surrounding environment so they could guide him or her and get relevant feedback.

7.2.10 Imbrication 10 (Material → human)

4) The material agency of the technology provides opportunity for new affordance(s).

Hence, at specific times, the architects and engineers looked and walked around in the 3D models using a traditional PC display only, while at other times, they used the head-mounted display together with or without the traditional PC monitor but still facilitated by the new plug-in. They used these combinations mindfully by first letting the clients look at the 3D model on a PC monitor while an architect walked through it, pointing to specific issues included in their agenda. This helped them to facilitate an intuitive understanding between meeting participants while the user of the head-mounted display was able to interact with the surrounding environment so they could guide him or her and get relevant feedback.

During my observations, situations arose that illustrated how they used the new plug-in together with a PC monitor to explain issues with a design. For instance, at one point meeting participants were sitting in a room, around a table. On the table were some 2D drawings printed on paper, plan drawings, elevation drawings, and perspective drawings. When the project architect came into the meeting room, he brought with him a laptop on which he had a 3D model of a house. Later during the meeting, the project architect began to walk through the 3D model of the house. While walking through the model, they were all on the one side of the table looking at the screen. Some of them were sitting, three or four of them, while the rest of them were standing behind the project architect who sat with the computer in front of him. When walking through the model of the house, the partner architect was pointing to the laptop screen showing and explaining some details of the house. This showcasing of the house seemed to last for around 10 to 15 minutes only. After that they closed the laptop screen and continued the meeting.

By walking through the 3D model, the architect was better able to manage the feedback and get the right amount and type of information from the meeting attendees while also having the possibility of referring to the physical 2D drawings. Additionally, he managed to make the clients present during the meeting understand the specific issues in an intuitive way by utilizing the plug-in’s vivid graphics and its affordance of walking through the model. In this instance as well as in other instances, the architects and engineers managed to create an equal dialogue through the immersive capabilities of the plug-in and a traditional PC monitor, in turn getting relevant feedback. By doing this, they avoided client and user feedback leading to a focus on potentially irrelevant issues which, if not taken seriously by the architects and engineers, could result in a bad relationship between the two parties. Or alternatively, result in a higher workload for the architects and engineers as they would have to do more work during the organizational design routine.

The head-mounted display, on the other hand, was only introduced at the end of the client and user meetings. At this point, the negotiations and important decisions had already been made. In particular, they utilized the immersive properties of the head-mounted display to summarize what they had talked about during the meeting but also to impress the client.

Together the head-mounted display, the PC monitor and the plug-in helped them to reach an agreement. The architects and engineers thus made use of the immersive capabilities of the head-mounted display while not being constrained by its materiality, its inclusiveness, that shut off the customer from the surrounding environment:

> *"Near the end…because, with stuff like this* [the head-mounted display] *is when people get a little bit excited, and then the meeting becomes a little bit more chaotic, and it's only one person who can try* [the head-mounted display]*...when it's only one person concentrating, other people will start chatting, so we do that near the end. And it is...a little bit like a summary to whatever we talked about* [during the meeting]*; 'This is how it all comes together.'"* (Interview – Architect).

In summary, the agency of the two displays, the head-mounted display and the PC monitor, as well as the plug-in helped them to make clients get an intuitive understanding. The displays through their immersive capabilities and the plug-in through allowing the clients and users to discover the 3D models in the immersive VE by letting them walk and look around in a natural manner.

5) The affordance(s) interact(s) with the <u>organizational routine,</u> which might lead to <u>change</u>.

On this background, they maintained these performances in the meeting routine of which the head-mounted display was a part. This development is in contrast to imbrication 8 in which the head-mounted display was seen as constraint which could potentially un-enroll it of the organizational meeting routine. To elaborate, in imbrication 8, the head-mounted display was seen as a constraint because they used the head-mounted displays without considering e.g. the risk of unwanted feedback, while being unaware of the paradoxical effects of the material aspect of head-mounted displays, inclusion, which on the one hand enables an intuitive understanding but on the other hand shuts the users off from guidance, colleagues, and other physical artifacts.

However, in this imbrication they had learned from the imbrication 8 and changed (or rearranged) the head-mounted display by using it mindfully at the end of each meeting to provide clients and users with an intuitive summary which helped them to agree on possible changes to the design of the project. During the organizational meeting routine, they used the non-inclusive PC monitor together with the plug-in which could help the clients and users to understand changes, by allowing them to walk through the models – either by themselves while being guided by a professional or by letting them see the changes as the architect or engineers walk through the model. In this manner, what they experienced was less immersive compared to the head-mounted display but it allowed them to create an intuitive and equal dialogue between the participants while being able to refer to the surrounding environment (other meeting participants and physical artifacts). In addition, the less inclusive PC monitor further allowed the architects and engineers to steer their attention and thus feedback in a relevant direction.

Collectively, the use of the PC monitor, the plug-in, and the head-mounted display changed the performances of the organizational meeting routine as it made them achieve their goal of facilitating an intuitive understanding between meeting participants while being able to interact with the surrounding environment so they could guide the clients and users and get relevant feedback.

The immersive capabilities of the head-mounted display combined with the non-inclusive but more flexible PC monitor and the plug-in helped the architects and engineers to achieve their aforementioned goals, leading to a more productive organizational meeting routine. In turn, the ostensive pattern of which the head-mounted display was a part, was this time around kept as an alternative way to involve and collaborate with users and often in combination with the less inclusive and thus less immersive but flexible PC monitor. Because the head-mounted display's materiality could not be changed, it was dependent on the existing infrastructure of past technologies and organizational routines for it to become part of the ostensive pattern of this organizational routine. The architects and engineers therefore saw this more immersive ostensive pattern as matching with their current goals.

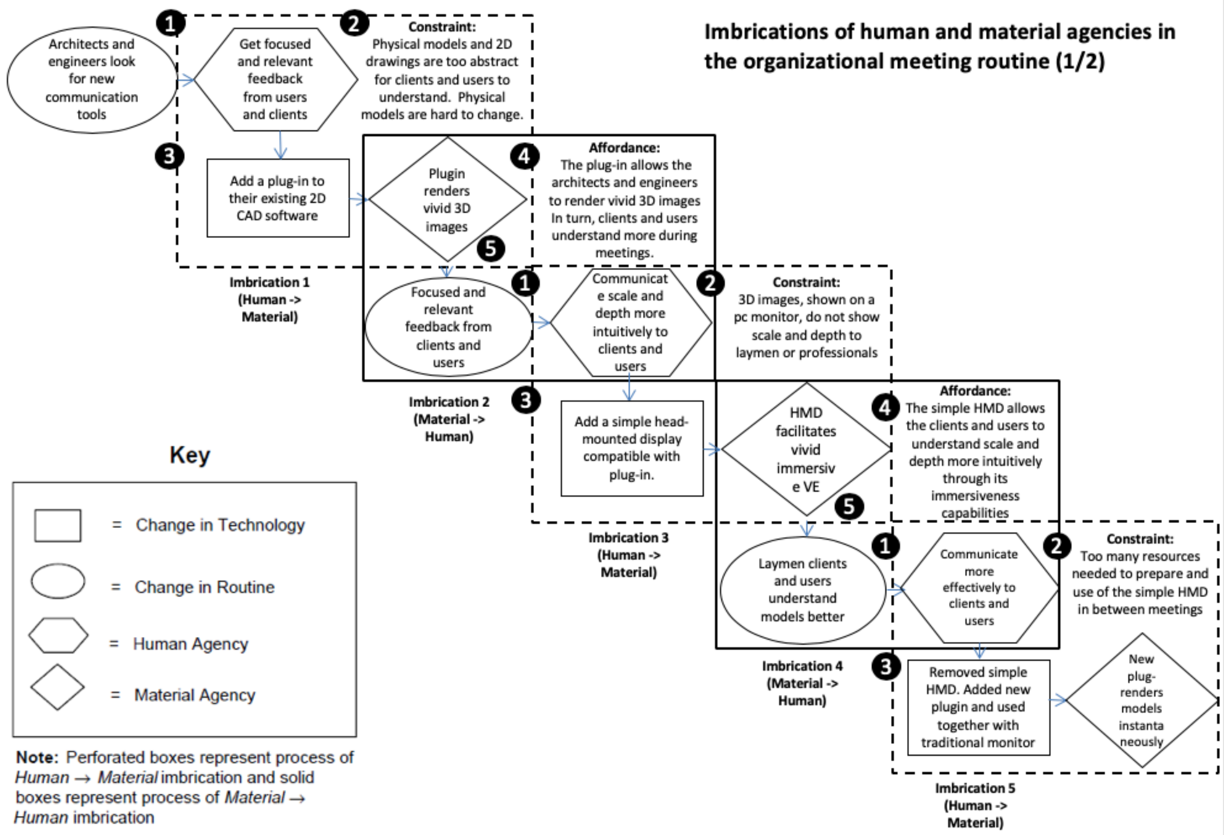
In turn, this made it possible for them to use this ostensive pattern of actions of which the affordances of the head-mounted display were a part, in the following ways.

First, they could use the ostensive pattern as a guide for the actions they should take during the organizational meeting routine, which would then help them guide their own performances as well as the performances of the clients and users.

Second, as it matched their goals by not constraining their actions, they could also legitimize and explain their actions internally to colleagues.

And lastly, the architects and engineers were able to identify what future actions they should take during the meeting routine by e.g. eliciting relevant feedback from the clients and users. And because they could use this ostensive pattern in these three important ways, the affordances of the head-mounted display remained part of the organizational meeting routine.

Overall, by using the head-mounted display together with the other tools available it contributed not only to the goals of this last imbrication but to the overall goal of the routine: to show the status of the project to the clients and/or to get feedback from the clients or the future users of the building so that the architects/engineers could move forward with the project.



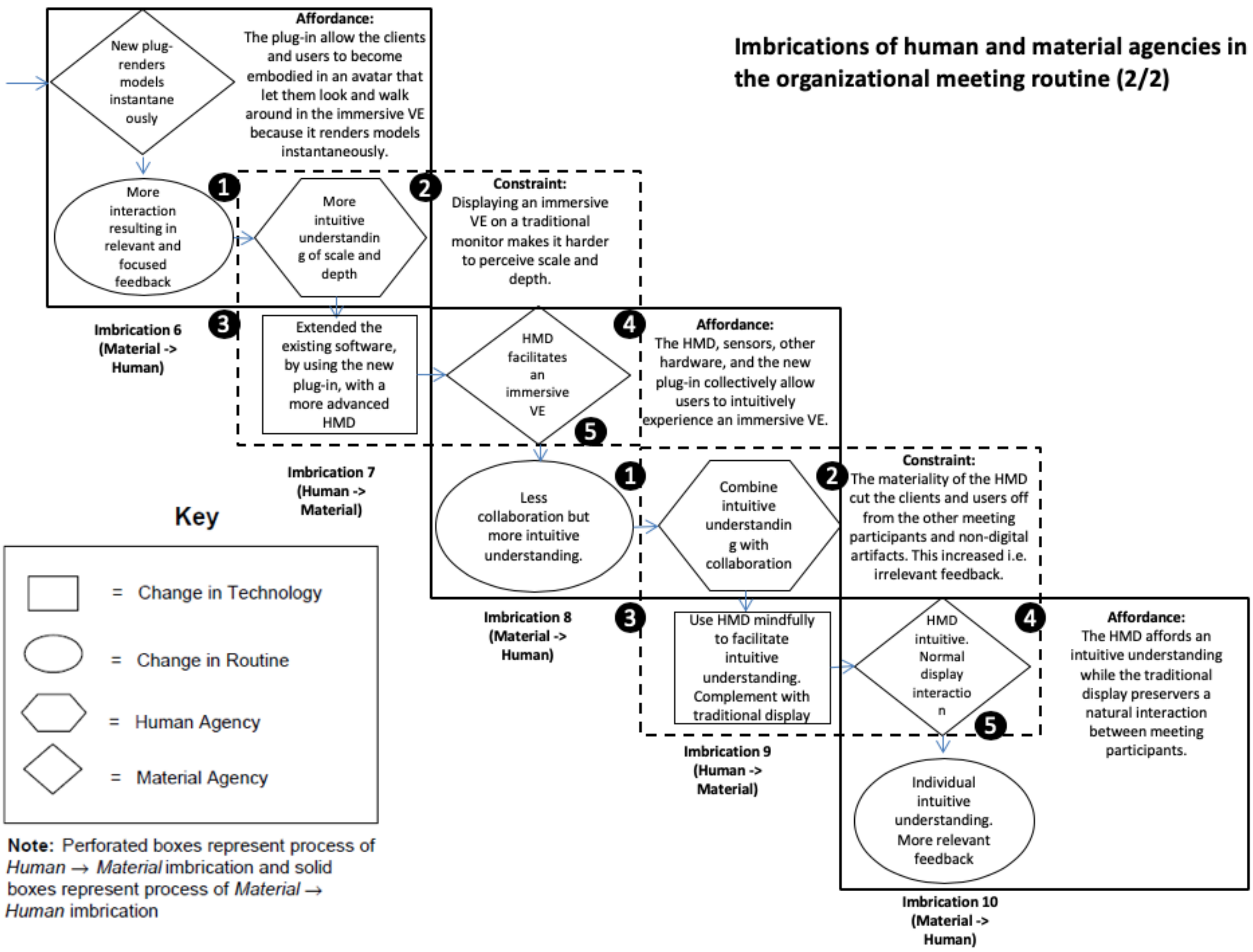


Figure 18: Illustration of imbrications in the organizational meeting routine.

7.3 Findings of the longitudinal analysis

7.3.1 Internal routine: organizational design routine

The overall purpose of this internal organizational routine is to design artifacts such as 2D plans or elevation drawings, walkable 3D models of whole buildings, and screenshots of 3D-rendered buildings, which can all then be used in meetings with collaborators, clients, and users.

The starting point for using more immersive technologies was in the initial imbrications, **imbrication 1 and 2**, where the employees at the architect company wanted to complement and eventually replace physical models with immersive 3D-rendered images by enrolling a plug-in allowing the architects and engineers to produce vivid 3D-rendered images. The purpose of this change in technology was to enable them to create artifacts that communicated their idea of a building project to clients clearly and effectively – professionals and laymen alike. However, while the technology made the organizational routine more effective because they could adjust and test models more quickly using 3D images instead of physical models, in this transition they realized that they had lost the ability to communicate scale and depth clearly to the clients and users during the organizational meeting routine.

To alleviate this constraint, the following imbrications, **imbrication 3 and 4**, showed that they acquired a simple head-mounted display which could help them to communicate their idea, including the scale and depth, of a building project to clients, clearly and effectively. As they started to use it during the organizational meeting routine, they also started to use it internally as they gained some of the same benefits experienced by the layman clients and users – a better perception of scale and depth. However, as they started to use this head-mounted display more often, they recognized some issues which made it hard to legitimize the use of this alternative ostensive pattern of which the head-mounted display was a part.

In particular, **imbrication 5 and 6** show that while they could communicate things more clearly internally to each other, they discovered that the preparations needed for using it were simply too laborious. They consequently wanted to be able to communicate their idea of a building project, including the scale and depth, clearly but also more effectively to each other. Hence, they acquired a new pair of more immersive head-mounted displays, as well as a plug-in which made it possible to first of all make the head-mounted display compatible with their existing software, but also to not only look but also walk around in vivid 3D-rendered models. However, while using the head-mounted display, the architects and engineers were shut off from the surrounding environment due to the materiality of the head-mounted display – the form and matter of the plastic casing. In this way, the use of the head-mounted display made the organizational design routine more individualized than it was before. Consequently, the alternative ostensive pattern, of which these more immersive technologies were a part, was put into question as the users could not use the new ostensive pattern to refer and make sense of their current actions together with their colleagues. They could only use the ostensive pattern to refer and make sense of their current actions individually.

In **imbrication 7 and 8,** they therefore sought to make their new ostensive pattern, which involved the new and more immersive technologies, more collaborative while maintaining the benefits of the immersive aspect of the technologies. The imbrications show that the materiality, the form and matter of the head-mounted display, cut its users off from colleagues. In addition, when designing both individually and together with others, they often needed to consult other non-digital artifacts which was not possible when they put on their head-mounted display as the material properties of the device shut them off from their surrounding environment. Therefore, they started to model and render 3D models using the new plug-in, but instead of putting on the head-mounted display they simply viewed the rendered model on a traditional monitor. In this manner, they could discover errors while also being able to collaborate with their colleagues and consult non-digital artifacts during the design process.

Because they used these more immersive ostensive patterns at different times, the materiality of the head-mounted display could be circumvented due to both the flexibility of the technology and human actors involved in the organizational design routine. This was especially due to the plug-in's compatibility with both the displays and the actors' technical competences which allowed them to appropriate the technology in a way that suited their goals. This in turn meant, that the ostensive patterns could be used by the actors as a guide for their future performances and as a way to account for and refer to past and current performances which match with their goals.

7.3.2 External routine: organizational meeting routine

The main purpose of the external organizational meeting routine is to show the status of the project to the clients and/or to get feedback from the clients or the future users of the building so that the architects/engineers can move forward with the project.

As was the case with the internal organizational routine, **imbrication 1 and 2** show that their main motivation for wanting to move away from physical models was to get focused and relevant feedback from the meeting participants, and in an effective manner. That is, the vivid 3D images could potentially communicate more clearly to the meeting participants as they were more detailed than the physical abstract models. But in addition, they were also more effective in communicating new ideas because they were easier to change and edit than the physical models. Therefore, the vivid 3D images, created by a flexible plug-in that could be easily integrated into their existing infrastructure of previous technologies and organizational routines, now slowly replaced the physical models and became the preferred ostensive pattern.

However, as the following imbrications show, **imbrication 3 and 4**, as the vivid 3D images slowly started to replace the physical models, they realized that the vivid 3D images could not provide the same level of scale and depth to the clients and users that the physical models did. And because they did not want to go back to using physical models only, they sought for a new digital technology that could enable especially non-professional users to understand the scale and depth of buildings in an intuitive way. They therefore acquired a simple head-mounted display whose immersiveness provided clients and users with an intuitive understanding of scale and depth as they could look around in a natural manner while being less aware of their surrounding environment, when they wore the head-mounted display during meetings.

As they started to use the head-mounted display, see **imbrication 5 and 6**, they discovered that while the head-mounted display had provided clients and users with an intuitive understanding of e.g. the scale and depth of a church project, the preparations needed for designing the 3D images that the head-mounted display used was simply too laborious. Consequently, a new human agency was initiated by the architects and engineers which sought a way to make meeting participants understand the scale and depth of projects intuitively but effectively. To remedy this lack of efficiency, they acquired a new plug-in which enabled them to not only look around in 3D images but also to walk around in 3D models.

However, while this allowed them to become more effective and at the same time let clients and users better understand the scale and depth of 3D models of future projects, they had lost another aspect. Especially since their existing head-mounted display was not compatible with this new plug-in, they had to disregard the head-mounted display and thus they had lost the intuitive understanding of scale and depth which immersion provides to users. Hence, in **imbrication 7 and 8** they accordingly set a new goal: to make clients and users understand depth and scale in an intuitive way, in turn easing communication between the meeting participants. And to overcome the constraint they see in their current technology, they extended the new plug-in, that generated 3D models, with a new type of head-mounted display. Now users could experience the buildings in real dimensions and enjoy the psychological experience of being there – just like their first attempt with the simpler head-mounted display allowed its users to do. Consequently, the potential for experiencing a more intuitive way of the 3D model was more likely. Furthermore, the head-mounted display and the plug-in enable the architects to communicate design changes and decisions to clients and in a more intuitive manner. This in turn helped the architects and engineers to make the design process more transparent and easier to understand for especially non-professional clients. And by being able to do so, they avoid losing the trust of their clients because they can experience themselves that their concerns are recognized. The head-mounted display, as well as the flexible technological infrastructure it relied on, allowed the clients and users to achieve a more intuitive understanding of 3D models, resulting in more feedback from the clients as well as an increase in trust.

As the ostensive pattern of which the head-mounted display was a part became a reliable alternative, they discovered some constraints with this new and more immersive technology. In particular **imbrication 9 and 10** show that they saw the following three constraints when using the head-mounted display. First, while the materiality of the head-mounted display effectively immersed its users and helped them to intuitively understand the design or the changes that were made, they could not refer to the other artifacts in the room nor communicate with the other people present as their sight and, at times, their audio senses were shut off. This made it difficult for the architects and engineers to understand specific problems that the clients and users pointed out, even if the architects and engineers were following the user's view of the head-mounted display on a PC monitor, as the professionals could not experience scale and depth in the same intuitive way as the immersed user. Second, because of the materiality of the head-mounted display, its inclusiveness, the user of the display cannot see any of the physical artifacts in his or her immediate surroundings nor interpret the body language of the meeting participants in the room. Third, when clients and users were using the head-mounted display, the architects and engineers could not guide them or point out where the clients and users should focus. Without guidance, the feedback was often not relevant at that specific time of the project or was simply just irrelevant to the project as a whole, which lead to an inefficient organizational design routine. On the one hand, while the architects and engineers could simply disregard this feedback, it might, in time, also lead to a loss in trust between the two parties, potentially jeopardizing their collaboration and in the end the project as a whole. Due to these identified constraints, the architects and engineers now set a new goal which would allow them to facilitate an intuitive understanding between meeting participants while the user of the head-mounted display should be able to interact with the surrounding environment so they could guide him or her and get relevant feedback.

Accordingly, during meetings with clients and users they started to use the head-mounted display more mindfully while to a larger degree making use of a traditional PC monitor only. In particular, at specific times during the meetings, the architects and engineers looked and walked around in the 3D models using a traditional PC display only, and at other times, they introduced the head-mounted display together with or without the traditional PC monitor. By using the head-mounted display and the PC monitor mindfully at strategic points in time, they facilitated an intuitive understanding between meeting participants while the user of the head-mounted display was able to interact with the surrounding environment so they could guide him or her and get relevant feedback.

In summary, the agency of the two displays, the head-mounted display and the PC monitor, as well as the plug-in helped them to make clients get an intuitive understanding. The displays through their immersive capabilities and the plug-in by enabling the clients and users to discover the 3D models in the immersive VE by letting them walk and look around in a natural manner. The architects and engineers thus made use of the immersive capabilities of the head-mounted display during situations where less collaboration was needed, and were therefore not constrained by its materiality, its inclusiveness.

8 Discussion

The research question of this thesis is: *How does the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines?* In other words, I aim to understand how head-mounted displays, and other immersive technologies (e.g. the aforementioned plug-in that produces the immersive VEs), influence and interweave with organizational routines. In this chapter I present and discuss the outcomes of this inquiry.

To be more precise I initially present and synthesize the findings of the two studies, the explorative and longitudinal study. In the following section I build on these findings and show how they contribute to research. Lastly, I discuss the merits of the imbrication lens in relation to the socio-technical and (other) sociomaterial approaches.

8.1 Summary of the findings and analysis chapters

By viewing the performances and the ostensive patterns of organizational routines through the imbrication lens, a set of findings has emerged from both the exploratory and the longitudinal analysis. And each one of these findings help to answer my research question: how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

8.1.1 How the material matters when enrolling head-mounted displays

Through the imbrication lens, the materiality of technology is directly conceptualized and therefore seen as being distinct from the performances of the human actors and their intentions that are involved in organizational routines. This helps to shed light on the following aspects.

First, in both the exploratory and the longitudinal analysis, the materiality of the head-mounted display conditioned its users in predictable ways which had an influence on whether or not the head-mounted display was enrolled and retained in an ostensive pattern of the organizational routines. That is, the physical form and matter of the head-mounted display, its materiality, played an important role, with no exception, as its inclusiveness shut users off from the surrounding environment – although with different outcomes. In the case of General Contractor B, from the first exploratory analysis, the head-mounted display made the users feel a level of scale and depth. While in the case of the Product development company, it did not condition the users to feel immersed as they did not feel comfortable with being shut off from their colleagues – at least initially. From the second longitudinal analysis, a similar pattern was seen – that no matter the context, the materiality of the head-mounted display played an important role when imbricating with the organizational routines, whether or not it was enrolled and retained in an ostensive pattern. For example, in imbrication 5 and 6 of the organizational design routine, it became clear to the architects and engineers that the head-mounted display, despite its immersive benefits, could not be used in situations where they had to collaborate with each other, or when they had to frequently consult other non-digital artifacts as the plastic casing shut users off from the surrounding environment. This did not make them completely un-enroll the head-mounted display. However, its use was restricted to situations where it was necessary to understand the scale and depth of any given 3D model – just as in the case of the Product development company where it was mostly used in situations where certain aspects of large 3D models had to be communicated to clients. In other situations, the head-mounted display seemed not to work as intended as it did not immerse the user. For example, when several of the architects had to communicate with the user of the head-mounted display, during the organizational design routine, but they did not succeed, they had to turn him around physically. In this instance, the visual sense of the user of the head-mounted display was cut off from the surrounding environment but he had to pay attention to what his colleagues were saying. Thus, being aware of the surrounding environment he was not fully immersed in the VE.

Together, the exploratory as well as the longitudinal cases show the following. First, that no matter the context, the materiality of the head-mounted display conditions users in certain predictable ways across contexts – it shuts users off visually, at minimum, from the surrounding context. Second, whether or not immersion is achieved depends very much on the context, as indicated in several instances in all of the cases. Immersion is an emergent characteristic which is highly dependent on the surrounding context in which it is used. And even if the head-mounted display succeeds in immersing the user, it is not always preferable to choose an immersive technology such as head-mounted displays, as will be elaborated on in the following paragraphs. Third, if this rather inflexible but defining characteristic of head-mounted displays is not taken into account, namely its inclusiveness, it might end up not being enrolled.

Following the argument from the last point: How have architects then taken the inflexibility of the head-mounted display into account?

8.1.2 Both the technology and the humans are flexible

Through the concepts of the imbrication lens and its explicit conceptualization on materiality, the findings show that in order for actors to succeed in enrolling and retaining the head-mounted display in an ostensive pattern, some important conditions need to be fulfilled.

First, whether or not an immersive technology is enrolled in the organizational routines depends to a large degree on the existing infrastructure of previous and current technology and organizational routines. In the explorative study, this pattern was expressed in several cases. For instance, in the case of General Contractor A, they had to allocate many resources in the form of specialists to make their existing 3D CAD models work with the head-mounted display and just to help stakeholders utilizing it in the first place as it was not easy to set up. As a result, they did not enroll it in their organizational routines. In the case of Architect Company A, they utilized their existing technological infrastructure to connect their head-mounted display with a monitor to alleviate the inflexibility of its immersive materiality, the inclusiveness. This resulted in them enrolling the head-mounted display in situations where interaction with the surrounding environment was not a necessity. In the longitudinal case, the importance of previously laid down infrastructure was also evident when trying to understand if the head-mounted display was enrolled in existing organizational routines. In both routines, the simple head-mounted display was discarded as it was not compatible with the existing infrastructure of technologies and organizational routines. For instance, in imbrication 5 and 6 of the organizational meeting routine, the simple head-mounted display was un-enrolled as the architects and engineers had to model and render four separate images for each change they had to show to the client using the head-mounted display. And these modelling and rendering performances depended on a plug-in which took up to 30 minutes to render each picture. The head-mounted display as well as the plug-in it depended on were therefore seen as inefficient, or as a constraint, because they had realized through their intertwining performances with this technology that it simply was not worth their efforts. This made them change their goal from wanting a more intuitive form of understanding scale and depth (set in imbrication 3) to a new goal in imbrication 5: they wanted clients and users to understand the scale and depth of projects intuitively but also *effectively*. And with this new goal in mind, the head-mounted display and its technological infrastructure was now seen as a constraint and thus did not match with the architects' and engineers' human agencies and their ostensive pattern, created with the intent to let users understand 3D models only intuitively and *not* effectively. This example illustrates that whether or not an immersive technology gets enrolled and retained in an ostensive pattern of any given organizational routine, depends on the infrastructure of previous as well as current imbrications of technology and organizational routines.

A second important finding is that once an immersive technology is enrolled, whether or not it remains a viable alternative for the actors in the organizational routine depends on the flexibility/inflexibility of the immersive technology itself as well as the surrounding infrastructure. To elaborate, as the aforementioned example shows: when an immersive technology, such as the simple head-mounted display, constrains the goals of the actors involved in any given organizational routine, whether or not it remains a viable alternative depends on its flexibility but also the flexibility/inflexibility of the immersive technology itself of past imbrications of material and human agencies – in other words, the already laid down infrastructure of past technology and organizational routines in any given organization. To be more precise, as both the exploratory and the longitudinal cases show, the inflexibility of an immersive technology was often taken into account in the existing infrastructure of previously laid down technologies and organizational routines. For instance, in the Architect Company A, the inflexibility of the matter and form of the head-mounted display, the inclusiveness provided by its casing, was compensated for in the organizational routine. In particular, by utilizing it at times when less interaction was needed with the surrounding environment they could benefit from its immersive capabilities while circumventing its inflexibility – the casing of the head-mounted display. In Architect Company B, on the other hand, they could not circumvent the constraints they experienced due to the materiality of the head-mounted display. That is, when enrolling the head-mounted display in their organizational meeting routine, they discovered that they lost control to the clients. In particular, because of the affordances of looking and walking around in an immersive VE, they experienced that the clients were able to discover unfinished parts in the 3D models.

Thus, due to the immersive capabilities provided by the digital materiality, the affordances of looking and walking around, they lost too much control to the clients, which they could not compensate for by utilizing other technologies in the organizational routine, nor by performing their organizational routine differently. Consequently, the head-mounted display did not significantly change the ostensive pattern of their organizational meeting routine.

In the longitudinal case, the same finding was also present. Namely, that in order for the head-mounted display to remain part of the ostensive pattern, its inflexible materiality needed to be taken into account in the infrastructure of previously laid out technologies and organizational routines. For example, in the organizational meeting routine described in imbrication 6 and 7, they enrolled a new and more immersive head-mounted display in addition to a new plug-in. Together, this enabled the respective meeting participants to become more immersed into any given immersive VE. However, just as in the case of Architect Company B, they quickly discovered that they lost control over the users of the head-mounted display as the users suddenly provided them with irrelevant feedback, potentially delaying the project. However, in contrast to the other architect company, from the initial study, they compensated for this inflexibility by changing when in the organizational routine they should introduce the head-mounted display. In this way, they compensated for the inflexibility that the casing of the head-mounted display presented to them by changing the organizational routine as well as the existing technological infrastructure. The latter was changed by adding a more traditional PC monitor to the computer instead of the head-mounted display. The PC monitor was then used together with the plug-in to provide an immersive but less inclusive experience, compared to the head-mounted display, at strategic points during the meeting by letting e.g. users walk and look around in an immersive VE.

8.1.3 Taking immersive technologies' ripples of variation into account

When the agencies of immersive technologies and organizational routines imbricate, the two studies show that it is important to take their mutual influence into account not only within the imbricated organizational routine but also between organizational routines. This is important because it helps to understand whether or not the immersive technologies and their affordances are retained in any given ostensive pattern they have become part of and thus explains how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

The actors in the organizational routines should consider how more immersive technology creates ripples of variation not only within but also between organizational routines. That is, the longitudinal case showed that decisions made in one organizational routine could condition imbrications in other routines. To exemplify: in imbrication 3 and 4 of the internal organizational design routine, their main reason for acquiring and enrolling a more immersive technology in the organizational routine was the wish expressed by one of the partner architects to communicate their ideas clearly and effectively to non-professional clients and users, in the external organizational meeting routine, in order to avoid misunderstandings, among other things. To accommodate this wish, however, they also had to change the internal organizational design routine, as the subsequent imbrications show. In particular, in order to prepare for client and user meetings, they had to produce content for the head-mounted display and once done with the meeting, they also had to incorporate the feedback into their 3D models. In short, in order to explain why immersive technologies are sometimes enrolled in an organizational routine but at other times are not, it is important to consider more than the routine in question.

Furthermore, once an immersive technology was enrolled in the organizational routine, the study shows that it influenced not only the organizational routine in which it was enrolled but also the other organizational routine. And this influence across organizational routines further affected not only whether or not the more immersive technology was enrolled in the first place but also if it was retained in the ostensive patterns of both organizational routines. Thus, to understand why the head-mounted display did not completely replace the existing less immersive technologies in the organizational meeting routine, but “merely” complemented them, it is important to consider not only its influence in the organizational routine in which it is enrolled, but also how its use influences the other internal organizational design routine.

To exemplify: when the more advanced head-mounted display and a new plug-in were enrolled in the organizational meeting routine (imbrication 7 and 8), it initially helped them to make the clients and users understand the depth and scale of 3D models in an intuitive way, in turn easing communication between the meeting participants. However, as it was used in the organizational meeting routine, they experienced that the feedback from the meeting participants became more comprehensive and less focused because they understood more, but also because the architects and engineers could not guide them or point out where the clients and users should focus. Thus, because of the affordances that the immersive technologies provided to their users, they could now discover issues in a more intuitive way.

However, due to the materiality of the head-mounted display they could not be guided by the architects and engineers. In turn, the feedback was often not relevant at that specific time of the project or was simply just irrelevant to the project as a whole. On the one hand, while the architects and engineers could simply disregard this feedback, it might, in time, also lead to a loss of trust between the parties. On the other hand, making 3D models of every design suggestion that clients came up with required that they had to do much work in the organizational design routine.

Consequently, they decided to use these more immersive technologies mindfully and only when it was relevant to the clients and users to understand the 3D models in a more intuitive way. That is, because the immersive technology variations were diffused from the external to the internal organizational routine, the technology's role in both routines was reduced – despite the benefits provided by its immersive capabilities. Thus, whether or not a technology is retained in an ostensive pattern not only depends on the organizational routine in which it is enrolled but also on the other organizational routines on which the technology depends.

In summary, the findings from both the exploratory and the longitudinal studies show the following important points. First, the materiality of head-mounted displays conditions their users in certain predictable ways across contexts. Second, whether or not immersion is achieved depends very much on the context, which emphasizes immersion relational characteristics. Third, because head-mounted displays condition performances in predictable ways, this inflexibility needs to be taken into account in the existing infrastructure of technologies and organizational routines. To be more precise, whether or not an immersive technology is enrolled in, the organizational routines depends to a large degree on the existing infrastructure of previous and current technology and organizational routines. And once an immersive technology is enrolled, whether or not it remains a viable alternative for the actors in the organizational routine depends on the flexibility of the immersive technology itself as well as the surrounding infrastructure. Fourth and lastly, the actors in the organizational routines should consider how more immersive technology creates ripples of variations not only within but also between organizational routines.

Together, these four findings are important in order to understand how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

With these findings in mind, in the following section I will elaborate on and discuss how they contribute to research on organizational routines and IS literature on immersive technologies. Following that, I initially discuss the merits of the imbrication lens in relation to not only the socio-technical and (other) sociomaterial approaches, but also its potentially blind spots compared to other approaches in the aforementioned literature streams. The discussion is concluded by a presentation of contributions to practitioners within the AEC industry.

8.2 Contributions

In the following sections I will elaborate on how this study contribute to organizational routines research, to research on immersive technologies, and lastly to practice.

8.2.1 Contributions to organizational routines

This study contributes to organizational routines in the following ways.

First, by keeping what technology is separate from what it does together with humans, the form and matter of technologies can be directly conceptualized. As this thesis has shown, and as many scholars have already mentioned, materiality is important to include and theorize as a distinct phenomenon in order to understand how not only immersive technologies, but also IT in general change organizational routines. With my thesis I have shown how the imbrication lens and organizational routines theory can be combined to better understand how the materiality of immersive technologies changes organizational routines, as suggested by IS and organizational routines scholars alike (Feldman et al., 2016; Leonardi, 2012; Pentland et al., 2012; Robey et al., 2013).

Second, by distinguishing between what the technology is and what it does when intertwining with human actors in organizational routines, the technology and its distinctive material features become visible. This in turn helps to better understand under what circumstances, when imbricating with organizational routines, a technology is either flexible or inflexible. Being able to understand this consequently helps to understand, in more detail, when and how the materiality of the technology, and its agency, either constrains or affords the goals of actors in the organizational routines. This move clarifies the role that materiality has when interacting with organizational routines, in turn explaining why and under what circumstances a technology matters in organizational routines and at other times does not (Howard-Grenville and Rerup, 2016; Parmigiani and Howard-Grenville, 2011). For example, in Berente et al.'s (2016) studies of the implementation of an ERP system in NASA, they show how different elements of organizational routines adjusted dynamically, such as shock absorbers, to allow for a successful implementation of an enterprise information system that was otherwise rigid, as phrased by the authors. While they do mention that the material is changing, the changes is mostly up to the employees' ability to adapt the IT system and use it in unexpected ways. For example, by writing a type of data into a header field in the software which was not designed for that particular purpose. Today, however, IT systems are becoming more modular and this modularity is to some degree determined by the technology itself, but also by the abilities of the actors in the organizational routine. With this thesis, I contribute to organizational routines studies by introducing the imbrication lens into organizational routines studies. And by doing so means that the technology's materiality and how it determines the flexibility and inflexibility are directly conceptualized by keeping what technology is separate from what it does together with humans, when it imbricates. To be more precise, it is not the technology itself but how the existing infrastructure of organizational routines, created by past imbrications of human and material agency, explains how the materiality of the technology either affords or constrains actions and ultimately determines if it is retained in an ostensive pattern of the organizational routine. And by conceptually distinguishing between what a technology is (the infrastructure) and how it imbricates, the flexibility or inflexibility of the technology is conceptualized directly and more importantly, the role it plays for any given technology that is enrolled in or un-enrolled from an organizational routine. For example, when the simple head-mounted display constrained the goals of the actors involved in the organizational design routine, it was un-enrolled because it was dependent on the slower plug-in. However, if it was compatible with the new and more efficient plug-in, or if the architects or the engineers were somehow able to reconfigure it so that it was compatible with the new and more efficient plug-in, it might have remained a viable alternative and thus a part of the ostensive pattern of the organizational routine. This illustrates that the materiality of the technology as well as the organizational routine both play an important role and therefore need to be directly conceptualized by keeping the technology and organizational routines distinct from their agencies.

Current theories within organizational routines theory have provided many insights into this area. However, as argued in this section, the review of the literature shows that they predominantly use theories and concepts, like Actor-Network theory, that insist that organizational routines and artifacts are indistinguishable phenomena. By identifying this gap in organizational routines literature and using the imbrication lens to alleviate these shortcomings, I aim at contributing to organizational routines theory. In short, by introducing the imbrication lens to organizational routines theory, I contribute to this research stream by providing a way to better understand the role that materiality plays when trying to understand why immersive technologies sometimes *"...matter a great deal; at other times, they only minimally encode a routine and do even less to influence its ongoing use."* (Parmigiani and Howard-Grenville, 2011, p. 445).

Third, by using the imbrication lens I highlight how the agencies of humans and technologies interact within and between organizational routines. In doing so, I illustrate that technologies such as head-mounted displays, and the infrastructure they rely on, can mediate variation across routines, in turn affecting the stability of multiple routines. In this way, I underline the importance of taking into consideration the relations between organizational routines when aiming to understand how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. In particular, the findings show that imbrications in which the head-mounted display is a part, have spill-over effects not only within but also between organizational routines, carrying wider variations across many organizational routines. The more feedback generated in the meeting routine, the more work to be done in the organizational design routine. Utilizing the head-mounted display in one organizational routine can have consequences for other organizational routines. For example, the irrelevant feedback generated from the users in the organizational meeting routine increased architects' workload during the internal design routines. To limit this, the architects and engineers made use of the head-mounted display at strategic points in time during the external organizational meeting routine. Thus, by using the head-mounted display less frequently, they limited the potential workload not only in the external organizational meeting routine but also in the internal organizational design routine.

Consequently, I show how immersive technologies can create variations across organizational routines, in turn contributing to organizational routines research. In particular, I show how an immersive technology, such as head-mounted displays and plug-ins, interacts to create variations not only within but also across organizational routines. I thus reiterate the importance of moving: *"...beyond organizational routines as the unit of analysis and consider relations among routines and networks of routines"* to better grasp how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines (Feldman et al., 2016, p. 511).

The above-mentioned leads to the fourth and last contribution to organizational routine research. With this thesis I aim to contribute to research on organizational routines by laying the foundation to a deeper integration between the organizational routines theory and the imbrications lens (see Figure 19), as suggested by scholars engaged in organizational routines theory (Feldman, 2016; Pentland et al., 2012). By integrating the two theoretical perspectives further, it would be possible to conceptualize more explicitly what happens when technology changes organizational routines (material → human). Currently Leonardi only hints what happens by saying that: *"…when they become imbricated – interlocked in particular sequences…they together produce, sustain, or change either routines or technologies"* (Leonardi, 2011, p. 149). It is suggested that when the material and human agencies imbricate, they produce, sustain, or change organizational routines. But if an organizational routine is changed or modified what precisely is it that is changed in it? Is it the ostensive pattern, the performances, or both? And if a new organizational routine is created – how is it created?

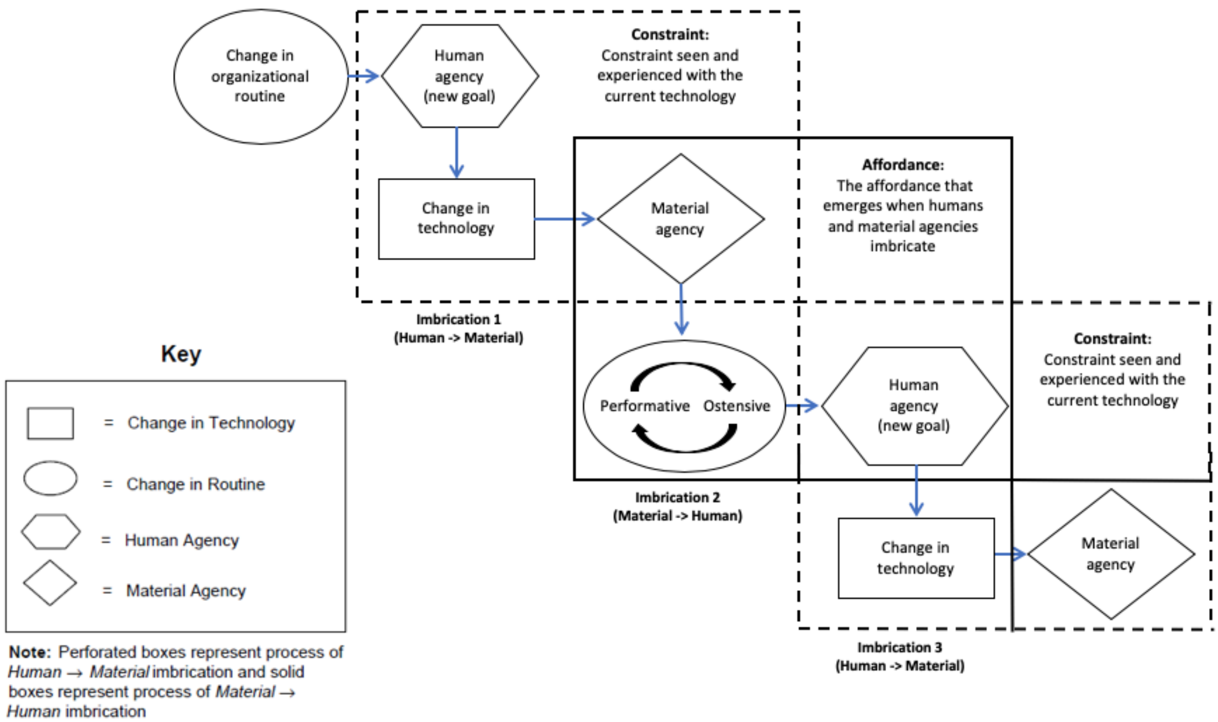


Figure 19: Integration of the imbrication lens and organizational routines theory.

In particular, I have suggested that if a technology is enrolled in an organizational routine, the affordance can create a new or modify an existing ostensive pattern. This ostensive pattern, of which the technology is a part, should then be able to help the actors to do one or more of the following things in order for the technology to be retained in the new/modified ostensive pattern: help the actors to make sense of their current performances, legitimize their performances retrospectively, or help them to guide their future performances. In this manner, the actors would then be led to repeat and recognize the ostensive pattern, and performances, of which a head-mounted display could be a part.

Alternatively, a technology might be un-enrolled or modified if the actors see the technology as a constraint. This can happen in one or more of the following ways. First, a technology can simply have issues which can cause the actors to not maintain it by simply avoiding using it in their performances. Second, actors can perceive a technology, and the ostensive pattern it is part of, as constraining if the ostensive pattern cannot be used to make sense of actors' current actions. Third, if the ostensive pattern cannot be used to legitimize actors' performances retrospectively. And lastly, if the ostensive pattern cannot be used to make sense of actors' performances prospectively.

However, as indicated, some organizational routine scholars suggest integrating the imbrication lens more tightly with organizational routines, but this has not yet been done within organizational routines research. In addition, to the author's knowledge, no empirical or theoretical studies exist that go into depth with the organizational routines theory in current IS research and how these two theories relate. While this study provides a foundation it also indicates that additional theorizing between the two perspectives needs to be done in order to better understand how and what aspects of organizational routines change.

8.2.2 Immersion as an emergent and relational characteristic of technologies

This thesis contributes to the IS research literature on immersive technologies. The current IS research on immersive technologies takes a stand that favors a view in which the technology is assumed to maintain its immersive capabilities regardless of the context, while the hardware is often black-boxed (Cahalane et al., 2012; Hofma et al., 2018; Schultze and Orlikowski, 2010). To reiterate, current theories within research on immersive technologies, including immersion, take a stance which does not take the surrounding context in account when assessing whether or not any given technology might provide immersion to its users – their immersive properties are somewhat fixed and assumed beforehand (Schultze and Orlikowski, 2010, p. 814). In other words, current scholars within research on immersive technologies tend to put too much focus on the immersive technology while not attending to how the materiality of it and these capabilities might interact with the surrounding environment to create unpredictable consequences for organizations. This is because the concept of immersion originates from the engineering sciences where focus tends to be on the technology while favoring methods that focus on identifying measurable and essential characteristics of these immersive technologies (Cahalane et al., 2012).

However, by using the imbrication lens together with qualitative methods I have shown how the materiality of the head-mounted display can facilitate immersion, at certain imbrications, and therefore works as the architects intended – while in other cases, the materiality of the head-mounted display constrains the architects' goals and therefore does not facilitate immersion. Thus, I argue that the immersiveness of head-mounted displays, and other immersive technologies, depends on how it intertwines and imbricates with human agencies and other technologies. In this way, I extend the theory on immersive technologies by attending to the relational and emergent characteristics of immersion – an aspect that has been undertheorized in current research on immersive technologies (Cahalane et al., 2012; Schultze and Orlikowski, 2010).

I illustrate that whether or not immersiveness is achieved is highly dependent on the relations that emerge in the context where immersive technologies such as the head-mounted display are used. To exemplify: while the materiality of the head-mounted display's casing does condition its users in certain predictable ways, by shutting the users off, its affordances were not always perceived. Instead, the use of head-mounted displays constrained their users in often unpredictable ways by for example limiting communication in all collaborative stages of the organizational routines because they constrained discussions and negotiations, especially. Hence, the architects combined less immersive 2D/3D artifacts in the collaborative stages of the routine with head-mounted displays at strategic points in time. This allowed them to achieve both goals simultaneously: help the layman clients and users to understand the drawings while creating a more focused type of feedback.

By demonstrating perceptions of constraints and not only the positive effects of immersive technologies, as was done in earlier IS studies (e.g. Mäntymäki and Riemer, 2012; Venkatesh and Windeler, 2012), these findings provide an alternative explanation of how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

8.2.3 Contributions to IS literature on immersive technologies and adoption

Recent studies on immersive technologies have shown how the inclusiveness, provided by for example head-mounted displays, can affect the adoption of them – however, with contradicting result (Steffen et al., 2019). In particular, Steffen et al. (2019) investigated why immersive technologies like VR have not been adopted to the extent that many scholars and practitioners have expected. To better understand this paradox they created a theoretical framework of affordances which should serve as a foundation of theoretical understanding of the motives behind the adoption of immersive technologies such as head-mounted displays (Steffen et al., 2019, p. 685). In their study they identify a significant modifier for users to experience the affordances of VR and thus for organizations to adopt VR. In other words, if the surrounding physical context is important for the users in any given activity, they theorize that it might have a significant effect on organizations' willingness to adopt and use VR. However, in their subsequent testing of this hypothesis, they identify contradictory results as one study shows that the importance of the physical context does indeed modify users' chance to experience the affordances of head-mounted displays, while their second study shows the opposite. This in turn leads them to conclude that more research should continue to explore when or at which point the desire to enact affordances provided by head-mounted displays is diminished by the presence of the aforementioned modifier (Steffen et al., 2019, p. 719).

With this thesis focus on the emergent and relational characteristics of immersion, I shed light on these contradictory results and thus contribute to research on immersive technologies. In particular, by moving away from the typical studies of immersive technologies which focus on software immersion and/or the technology alone, with this thesis I broaden the scope to include not only the technology itself but also how it intertwines with organizational routines.

Together, these aspects show that the physical context does indeed play an important role as the users constantly need to interact not only with colleagues but also with other non-digital artifacts in both organizational routines. And these factors have an important influence on how and under what circumstances head-mounted displays are enrolled and retained in the ostensive patterns of organizational routines. To exemplify, in imbrication 5 and 6 of the organizational design routine it became clear to the architects and engineers that the head-mounted display, despite its immersive benefits, could not be used in situations where they had to collaborate with others or when they had to frequently consult other non-digital artifacts as the plastic casing shut users off from the surrounding environment. This did not make them completely un-enroll the head-mounted display. However, its use was restricted to situations where it was necessary to understand the scale and depth of any given 3D model. Thus, when they had to collaborate or consult non-digital artifacts, they preferred to use other less immersive but more flexible technologies, e.g. walk around in the immersive VE using a traditional monitor, or analogue artifacts such as paper and pen.

As the example above also shows, not only the context but also the materiality of the head-mounted display plays a significant role when trying to understand how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

In the following section I elaborate on how I intend to contribute to practice with this thesis.

8.2.4 Contributions to practice and the AEC industry

The AEC industry in general has productivity issues (McKinsey, 2017; World Economic Forum, 2016). Compared to the general growth in productivity, but also to other comparable sectors such as the manufacturing industry, productivity has been below average. On a global scale, this industry's labor productivity growth has averaged 1 % a year over the past two decades. In comparison, the global average has been 2.8 % for the total world economy and 3.6 % for the manufacturing industry (McKinsey, 2017; World Economic Forum, 2016). Because of the size of the AEC industry, being among the largest in the world with about $10 trillion spent on construction-related goods and services every year, even small increases in productivity could have a big economic but also environmental impact as it is the largest consumer of raw materials, accordingly accounting for 25–40 % of the world's total carbon emissions.

The low levels of productivity in this industry are to a great extent due to the fact that the industry is highly fragmented and consists of many specialized firms such as architect firms, plumbers, engineering consultancies, and large general contractors. Because of its nature, each building project requires many different specializations which are often subcontracted by larger firms. For example, in many of the projects done by the architect firm from the longitudinal case study, they often subcontracted parts of projects to engineering consultancies, or they were subcontracted themselves. Thus, collaboration with not only clients and users but also professional colleagues is an important element in the design process of any given project. In fact, issues often arise between stakeholders involved in projects which lead to distinct understandings of contracts and in general to a: *"...hostile contracting environment"* (McKinsey, 2017, p. 8). Similar problems have also been identified in especially the longitudinal case where several of the interviewees underlined the importance of communicating changes to clients and users in order to uphold a productive environment and trusting collaboration between clients, users, and other professional collaborators involved in any given project.

By introducing more immersive technologies, such as head-mounted displays and plug-ins that produce immersive VEs, this thesis shows how and when companies within the AEC industry can use these immersive technologies to communicate issues more clearly to stakeholders, professionals, and laymen alike, during the design phase of building projects. In particular, in line with Colbert et al. (2016), I argue that immersive technologies could be useful in virtual teams so that they can feel closer to each other. However, I also show that in physical teams, practitioners should consider giving their clients head-mounted displays before the meetings or when doing individual work. During meetings, as well as during discussions, negotiations, and collaborations, physical teams should opt for a lower level of immersiveness by incorporating other artifacts. If they utilize immersive technologies for collaborative work, like head-mounted displays, which is becoming increasingly more common (Gartner, 2017), professionals should ensure that the technology can be appropriated in a flexible manner that allows for both individual and collaborative interactions with other people and artifacts.

In the following and last section of the discussion I will discuss how two alternative approaches to the imbrication lens could have been used to shed light on the research question of my thesis.

8.3 The relevance of the imbrication lens: A comparison of approaches

The imbrication lens offers a view that is distinctive from other similar approaches, the socio-technical systems and the sociomaterial approach (Cecez-Kecmanovic et al., 2014; Leonardi, 2012). In the following section, I will initially reiterate arguments for why the imbrication lens, sometimes put under the umbrella term socio-materiality (with a hyphen), is relevant to literature on immersive technologies and organizational routines (Leonardi, 2012). Against that backdrop, I will then initially discuss how a socio-technical systems approach differentiates itself from the imbrication lens and how it could have contributed differently to my thesis. Next, I do the same with the sociomaterial approach. I conclude this section by arguing for why the imbrication lens is best suited to answer the research question of this thesis: *How does the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines?*

8.3.1 The imbrication lens: its relevance to this thesis and research

The main arguments for employing the imbrication lens are twofold. On the one hand, I argue that it is important to maintain an ontological distinction between technologies and humans and their respective material and human agencies. While on the other hand, it is also important to preserve a relational ontology. Together, this provides a way to highlight the unique and defining material features of the primary phenomenon under investigation, head-mounted displays and their inclusiveness, while remaining open to the myriad of ways in which material and human agencies imbricate, to create infrastructures of technologies and organizational routines. These two points are important to research on immersive technologies and organizational routines.

Most IS research on immersive technologies takes a stand that favors a view in which the technology is assumed to maintain its immersive capabilities regardless of the context, while the hardware is often black-boxed. The imbrication lens, on the other hand, reframes immersion as a relational and emergent phenomenon while being able to distinguish the different hardware and software that facilitates immersion. Together, this allows to explain how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

Much literature within organizational routine research do provide a vocabulary that helps to understand technologies' relational characteristics and features of technologies especially. However, the review of these articles also showed that they argue for an ontology that privileges neither humans nor nonhumans by using the vocabulary of Actor-Network theory. When using this vocabulary, they tend to focus on the actions that humans and technologies, e.g. actants, perform together. In this way, they do provide a vocabulary that do not directly focuses attention on the materiality of technologies.

The imbrication lens, on the other hand, provides concepts and a vocabulary that directly theorizes the materiality of head-mounted displays, its agency and how it imbricates with human actors that are part of organizational routines. Thus, I argue for more studies within the practice perspective of organizational routines theory, to introduce the imbrication lens when dealing with phenomena where the materiality is of significant importance when trying to understand how technologies interweave with organizational routines.

8.3.2 A socio-technical approach and its potential relevance to this thesis

A socio-technical systems approach could be a relevant alternative, however, through its concepts of technical and social subsystems, as it does keep the social and the technical aspects ontologically distinct, potentially making it possible to directly conceptualize how head-mounted displays, and its related hardware and software, imbricate with organizational routines. In particular, a social subsystem directs attention toward social structures such as hierarchies, communication networks. Whereas the technical subsystem relates to not only the technology but also its "associated work structure" (Mumford, 2006, p. 321). The goal of socio-technical systems theory is to highlight the interdependencies between people and things. By doing so, socio-technical researchers aim at understanding and underlining that technology will be implemented and subsequently used in a social arena that will, to some extent, shape whether and how it is adopted (Leonardi, 2012, p. 11). In other words, if I applied a socio-technical system approach, the main focus would be on jointly optimizing the two subsystems, the social and the technical system, with the intent to improve performance of the organization and optimize the quality of work life (Mumford, 2006; Trist, 1981).

How would a socio-technical perspective then be different compared to the imbrication lens? The overall goal of the imbrication lens is to shed light on the following: *"when…employees…are unable to achieve their goals…how do they decide whether they should change the composition of their* [organizational] *routines or the materiality of the technologies with which they work?"* (Leonardi, 2011, p. 147). Or why do employees make the choices they do when facing this dilemma? Compared to the socio-technical approach, the imbrication lens, first, has a less normative goal. It is in other words more descriptive and less about optimizing two systems with the aim of increasing performance or the work quality of e.g. employees. The socio-technical approach could highlight important aspects of this thesis.

For example, in the data and subsequent analysis of my thesis, I have identified themes relating to especially efficiency and productivity in many of the goals that the employees have. Thus, a socio-technical approach would help to put this aspect more clearly into light compared to the imbrication lens. However, as the quote suggests, one of the main arguments for engaging with the imbrication lens is to put focus on a defining aspect of the head-mounted display – namely its inclusiveness. And as argued, the inclusiveness of the head-mounted display is tightly connected to its materiality – the matter and form of the casing, among other things. With the imbrication lens, I can directly conceptualize this aspect and how it interacts, shapes, and is shaped by previous and existing infrastructures of technologies and organizational routines.

These aspects are not the main focus of socio-technical systems theory. For instance, the concept of a technical subsystem does not address (only) the materiality of the technology but also the associated work structures that surround the technology. Hence, the emphasis from a socio-technical view is slightly different in that its unit of analysis is more on: *"...the properties of a technology that are used in various ways to support various tasks in the technical subsystem"* (Leonardi, 2012, p. 11) which tends to underestimate the matter and form of technologies, e.g. its affordances. Lastly, socio-technical scholars has in addition a historical tendency to focus primarily of social actions (Orlikowski, 2010, p. 133)

The imbrication lens takes the matter and form of technologies directly into account without privileging human interpretations and their agency, but by explicitly emphasizing how they mutually imbricate, shape, and constitute each other. This is not to say, that there is something "inherent" in socio-technical research that prevents the inclusion of the material and human (Robey et al., 2013). Many of the founding blocks of socio-material research in general, and in particular the imbrication lens, come from socio-technical research, though the imbrication lens provides a vocabulary that emphasizes a mutual shaping as well as an emergence of affordances which historically has not been prioritized in socio-technical research, resulting in accentuating either the technical or the social aspects (Cecez-Kecmanovic et al., 2014; Leonardi, 2012; Orlikowski, 2010).

8.3.3 A sociomaterial approach and its potential relevance to this thesis

A sociomaterial lens, such as Orlikowski and Scott's (2008) version of it, could also be an alternative way to shed light on how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, influence or interweave with organizational routines. Their proposition of sociomateriality, which has since been expanded and extended into many different directions (see Cecez-Kecmanovic et al., 2014), is based on an agential realist philosophy, as developed by Barad (2003). One of the main propositions of the ontology derived from agential realism is that the duality between the social and the technical aspect is challenged. Instead of seeing these two "entities" as having fixed boundaries and properties, they are seen as relational effects where the social and the technical aspects are *not* first separate entities and then interact to create relationships but: *"Each thing, including each* *person, is first and always a nexus of relations…all things, including all practices, have a shared being and a mutual constitution in this sense. They start out and forever remain in relationship"* (Slife, 2004, p. 159). This form of ontology is defined by the author as a strong relationality. With such an ontology, the distinction between the social and the material aspect is challenged and the focus therefore shifts from understanding how the social and the technical actors interact and influence each other, to a focus that tries to understand how their properties and boundaries are enacted and reenacted in practice or how and why some of these entities and their relations are stabilized. This performative ontology can be traced back to Pickering (1995) (Cecez-Kecmanovic et al., 2014) who utilizes a post-humanist view to deemphasize the role that humans play in humans' and technologies' mutual relationship and constitution of each other. And because he was inspired by Actor-Network theory, he persisted that both humans and technology (or more generally, nonhumans) have agency, while emphasizing that they mutually constitute each other when intertwining, as elaborated in the chapter on Philosophy of science. In contrast to Actor-Network theory and the sociomaterial view, without the hyphen, though, he insisted that humans, technology, and their agencies are different because human agency has intention while technology has materiality. Building on Pickering, among others, the imbrication lens (a socio-material view) thus differentiates itself from the sociomaterial view (without the hyphen) because they insist on keeping human and material agency, as well as the organizational routines and technologies they produce, at least conceptually, distinct from each other.

If I were to employ a sociomaterial perspective, instead of a socio-material one such as the imbrication lens, I would therefore shift the focus from how human and material agency intertwine and their imbrications to how they constitute themselves as entities. In relation to the literature on immersive technologies, this would also be productive in order to understand for example how some less immersive technologies create boundaries and actor-networks which potentially exclude other actor-networks, for example head-mounted displays. However, in relation to immersive technologies, my focus is more on how the agencies of head-mounted displays influence organizational routines to better understand under which circumstances immersion is more or less preferable. Furthermore, as highlighted in the section on organizational routines, organizational routines theory has predominantly utilized Actor-Network theory to give prominence to the material in organizational routines. Consequently, the ontological distinction between the material and human agencies is not being upheld. In addition, because they do not utilize a theoretical vocabulary that conceptualizes the material features of the technology, its matter and form, how that shapes and is shaped in the interactions with the existing infrastructure of technologies and organizational routines is overshadowed.

To summarize, both a socio-technical as well as a sociomaterial lens could provide an alternative view on how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. The socio-technical systems approach helps to better understand how to optimize the interactions between the social and the technical subsystems with the aim of increasing performance or employees work quality – where the former topic was present in many of the goals that the employees had. Common to both perspectives is that they do not directly conceptualize the materiality. In the socio-technical view, the focus is slightly different as a technical subsystem implies a slightly broader focus by focusing not only on the materiality of technologies but also on other more structural aspects. In the sociomaterial view, the materiality is less inclined to be focused on as well because there is not an emphasis on how humans, technologies, and their agencies are interacting but on how they for example create boundaries and become entities.

9 Conclusion and future research

With this thesis, I have aimed to contribute to a better understanding of how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines. In the aforementioned discussion, I have presented and elaborated on the findings of this thesis and how these findings connect and contribute to research literature. In this concluding chapter of my thesis, I will initially summarize the findings of my study before ending my thesis by suggesting research directions that could be further explored by IS researchers on immersive technologies and by organizational routines scholars in future studies.

In my thesis, I have set out to investigate the research question: *How does the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines?* In the pursuit of answering this research question, I have employed insights from organizational routines and Leonardi's (2011) imbrication lens. Tracing the imbrications of material and human agencies, I observed how they condition changes in organizational routines and technologies. By viewing the performances and the ostensive patterns of organizational routines through the imbrication lens, four findings have emerged from both the exploratory and the longitudinal analysis. And each of these has an important role in determining whether or not a technology is enrolled and subsequently retained in any given ostensive pattern of an organizational routine. Which should, in turn, help to explain how the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines.

The first of these four findings show that the materiality of head-mounted displays conditions its users in certain predictable ways across contexts, emphasizing how the material matters when enrolling head-mounted displays**.**

Second, whether or not immersion is achieved depends very much on the context, as indicated in several instances in all of the cases. Immersion is an emergent characteristic which is highly dependent on the surrounding context in which it is used. And even if the head-mounted display succeeds in immersing the user, it is not always preferable to choose an immersive technology like head-mounted displays.

Third, because head-mounted displays condition performances in predictable ways, their inflexibility needs to be considered in the existing infrastructure of technologies and organizational routines. This is true both when wanting to explain whether or not an immersive technology gets enrolled at all, and whether or not it remains part of the organizational routines. To be more precise, whether or not an immersive technology is enrolled in the organizational routines in the first place depends to a large degree on the existing infrastructure of previous and current technology and organizational routines. In the longitudinal study, for example, the importance of previously laid down infrastructure was evident when trying to understand whether or not the head-mounted display was enrolled in existing organizational routines. In both organizational routines, the simple head-mounted display was discarded as it was not compatible with the existing infrastructure of technologies and organizational routines. However, both studies also show that once an immersive technology is enrolled, whether or not it remains a viable alternative for the actors in the organizational routine depends on the flexibility of the immersive technology itself as well as the surrounding infrastructure. To elaborate, as the aforementioned example shows: when an immersive technology, such as the simple head-mounted display, constrains the goals of the actors involved in any given organizational routine, whether or not it remains a viable alternative depends on its flexibility but also on the flexibility/inflexibility of the actual immersive technology of past imbrications and its material and human agencies. In other words, the already laid down infrastructure of past technology and organizational routines in any given organization also plays an important role when trying to understand if an immersive technology continues to matter in organizational routines.

Fourth, and lastly, the actors in the organizational routines should consider how more immersive technology creates ripples of variations not only within but also between organizational routines. The longitudinal case showed that decisions made in one organizational routine can condition imbrications in others. Furthermore, once an immersive technology was enrolled in the organizational routine, the study shows that it influenced not only the organizational routine in which it was enrolled, but also the other organizational routine. And this influence across organizational routines had an influence on whether or not the more immersive technology was enrolled in the first place, but also if it was retained in the ostensive patterns of the organizational routines. To exemplify, when the more advanced head-mounted display and a new plug-in were enrolled in the organizational meeting routine (imbrication 7 and 8), it initially helped them to make the clients and users understand the depth and scale of 3D models in an intuitive way, in turn easing communication between the meeting participants. However, as it was used in the organizational meeting routine, they experienced that the feedback from the meeting participants became more comprehensive and less focused because the participants understood more, but also because the architects and engineers could not guide them or point out where the clients and users should focus. Thus, because of the affordances that the immersive technologies provided to their users, they could now discover issues in a more intuitive way. However, due to the materiality of the head-mounted display, they could not be guided by the architects and engineers. In turn, the feedback was often not relevant at that specific time of the project or was simply just irrelevant to the project as a whole. On the one hand, while the architects and engineers could simply disregard this feedback, it might, in time, also lead to a loss in trust between the two parties. On the other hand, making 3D models of every design suggestion that clients came up with required that they had to do much work in the organizational design routine. Consequently, they decided to use these more immersive technologies mindfully and only when it was relevant to the clients and users to understand the 3D models in a more intuitive way. That is, because the immersive technology variations were diffused from the external to the internal organizational routine, their role in both routines was reduced – despite the benefits that its immersive capabilities provide. Thus, whether or not a technology is retained in an ostensive pattern not only depends on the organizational routine in which it is enrolled, but also on the other organizational routines it is connected to and depends on.

Together, these four findings answer the research question of this thesis: *How does the matter and form of immersive technologies, for example head-mounted displays and its related software and hardware, imbricate with organizational routines?*

9.1 Future research

In the following section, I elaborate on future areas of research within immersive technologies, organizational routines, and the imbrication lens.

With the literature review on IS research on immersive technologies, I underlined that the typical paper has focused on software immersion. In addition, the level of analysis is heavily skewed towards the individual. This choice goes hand in hand with an overwhelming focus on adoption, use, and continued use, due to the frequent application of Davis's Technology Acceptance Model (1989) which is empirically measured quantitatively through survey data (see Cahalane et al. (2012) and Hofma et al. (2018) for more in-depth analysis).

While I try to allow for this by focusing on the materiality of immersive technologies within the AEC industry and by shifting the unit of analysis to the organizational level, this is only a start that other IS scholars can build on. In particular, by utilizing organizational routines theory and the imbrication lens, future research can potentially shed light on how head-mounted displays matter but at other times do not within other industries such as retail or healthcare. Alternatively, scholars could conduct multiple longitudinal case studies within the AEC industry, in other geographical contexts, to extend on the findings of this thesis. IS researchers could investigate if for example the materiality of head-mounted displays, their inclusiveness, condition users across contexts in the same way, and how it might impact their willingness to enroll head-mounted displays out in their organizational routines. A third suggestion would be for IS scholars to investigate the societal implications that immersion might have on the collaboration between employees and on inter-organizational collaborations, which in turn could extend our understanding of immersion as a relational and emergent concept and of its unintended outcomes.

My suggestions above for potential research may be fruitfully utilized by others for their organizational routines and the imbrication lens to shed more light on a rapidly developing technology with which current IS research, and the methodologies employed in IS, seems to be out of touch (Gartner, 2017; Steffen et al., 2019).

By applying organizational routines theory and the imbrication lens to an empirical context where immersive technologies are used, scholars can also incorporate and directly conceptualize temporality and spatiality of organizational routines – an area which is currently understudied in organizational routines research (Howard-Grenville and Rerup, 2016). For example, how does the performance of organizational routines in virtual space shape the evolution and interaction of artifacts and actions both online and offline? Or: *"…how clock time influences the performance of routines and how people's experiences of time shape routine performances".* These and similar questions regarding the spatial and especially temporal aspects of organizational routines can be addressed by supplementing the imbrication lens with organizational routines theory, as the evolution of organizational routines and technology is directly addressed by showing these as mutually developing through imbrications over time. Furthermore, as technologies are becoming increasingly more immersive, organizational routines actors will increasingly perform their actions in ever more immersive virtual spaces. Consequently, researchers need to ask important questions such as how: *"…the nature and interplay of these actions and* [their] [ostensive] *patterns differ"* (Howard-Grenville and Rerup, 2016, p. 13) from organizational routines performed in less immersive virtual spaces.

Lastly, I encourage scholars to further develop the integration of the two literature streams of organizational routines and the imbrication lens to better understand how the materiality of technology might change organizational routines and their internal dynamics.

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Appendices

Interview guide – The first explorative phase

Purpose:

- To hear about considerations regarding virtual reality and potential uses.
- Gaining insight into other similar immersive technologies e.g. CAD and / or 3D models

Background questions:

- Brief introduction of the organization
- How does a typical project progress?
- What role does the organization have in a typical project?
- What is/was your and the organization's role in a project?

About virtual reality:

- How have you used virtual reality?
- Does using virtual reality help your projects?
- Are there challenges in using virtual reality in your projects?
- Has virtual reality had any impact on your work processes?
- Have you thought about how to make better use of virtual reality?

Or/and

- How do you imagine Virtual Reality can be used?
- Could using virtual reality help your projects?
- Are there any specific reasons why you do not use virtual reality?
- Have you made any considerations regarding the use of virtual reality?

Others:

- Do you use digital tools when developing, planning and designing projects?

    - For example, CAD, 3D models, VDC or similar
- Does it help your development, planning or design process?
- Does it create challenges in your development, planning or design process?

Interview guides – The second longitudinal phase

The explorative interview guide

Purpose

These interviews seek to identify organizational routines that VR is enrolled in with the aim of understanding the changes that VR have on organizational routines.

To find relevant organizational routines interviews will be conducted with employees from four different projects. To identify the changes that VR will have on the organizational routines one of the four projects that is investigated will not have enrolled VR into its organizational routine and will in this way be compared to the aforementioned organizational routines that enrol VR.

The four projects are:

1. **Project A (2016-2020):**

Project A is currently in the later stages of the design phase (project design). During this phase they use VR to involve and explain users in specific design choices i.e. where to situate the lamps in the nave of the church. The design phase is finished in May 2018.

2. **Project B (2016-2018):**

Project B is an urban sports centre. It is set to open on the 23rd of February 2018. Currently, it's in the later stages of the building phase, meaning that the last details of the interior are being set up and designed by involving users. VR was mainly used during the design phase to sketch out the outer design of the building and the interior of the building.

3. **Project C (2016-2020):**

Project C is a combined church and cultural centre. It's currently in the last design stage (the local authorities need to accept the project). VR was and is used to communicate, discuss, and involve (layman i.e. the priests) users on design choices.

4. **[A project without the use of VR]**

Guiding Questions

<u>About the project</u>

- What is the status of the project? (What stage is it in?)
- What is your role in the project?

<u>Tasks/Routines</u>

- What is(are) your main task(s) in this project?
- What routine(s) is/are the tasks a part of?
    - Are other employees involved in that routine?

<u>Tools (Software, VR, etc.) used during routines?</u>

- What software do you use in general?
- Have you used VR?
    - Why/when/how?
- In what routines or tasks have you used VR?
- How have you used VR?
- How are the routine/task different when using VR?

<u>Specific VR Questions</u>

- When and why did you introduce VR?
- How are you using VR?

The longitudinal interview guide (focus on the ostensive)

Interview protocol

The interview recording will only be used by me to hear what you say some extra times to catch what you're saying. At some point I will also transcribe the recording myself and before I show it to anyone else (probably my supervisor and other academic collaborators) than myself I will show you the written transcription and ask you if it is okay and if you want something to be left out. Lastly you will of course be anonymized.

The interview should take less than an hour.

As you might know I'm interested in how you use VR and the impact of VR on your work processes. Therefore, VR and related programs are also very relevant for this talk.

To understand the impact of VR on your work processes, I will ask how different work processes are executed without the use of VR and with VR.

We will start by identifying a repetitive pattern of action you do as part of your work. It needs to have a definite start and finish. Ideally, it should involve more than one person (the other person might be a customer or a supervisor).

Once we have decided on the process to talk about, we will:

- Information on you
- About VR and related tools in general
- Get a general description of the process.
- Break the process down into steps.
- Identify the sequence of steps.
- Estimate the frequency of alternatives or exceptions.
- VR/Enscape and the process

Demographic questions

- How long have you worked here?
- What is your role:
    - In general

About VR and related tools

A1. Have you used or seen others use VR?

A1a. Yes:

- How many times have you used or seen others use VR?
- What was it used for?

A1b No, but I've used Enscape:

- How many times have you used or seen others use VR?
- What was it used for?

A2. What were/are your thoughts on VR/Enscape back then and now?

- Is/was it useful?
    - Why not?
    - When?
    - In what way?

- How does it complement your other tools if at all?

A2. How was the process of buying VR? Bottom-up/Top-down?

A2a. Yes:

- What were the intentions of buying VR in the first place?
- Has there been any formal introduction to VR?

A2b No:

- How were you introduced to VR?
  - Top-down/Bottom-up?

About the work processes:

Part 1: Get a general description of the process.

Q1. Let's start by getting a brief description of the organization and project. How would you describe this organization (not the name, but what it does).

Q1a: About the project: What is it about and what is the purpose/aim?

Q1b: What is the status of the project? (What stage is it in?)

Q1c: What is your role in the project?

Q2. Now let's identify a particular process to talk about. From our last meeting…

1. User Meetings/Workshops
2. Client meetings
3. Meetings with collaborators/partners
4. (Internal sketching and design)

Q4a. What is the purpose or goal of the process?

Q4b. Can you give me a broad overview of this process, from start to finish:

Q5. How often is the process done: _____________

Q6. I'd like to know how long it takes to complete, from start to finish.

Q6a. From start to finish, what's the shortest/fastest: _____________

Q6b. From start to finish, what's the longest/slowest: _____________

Q6c. From start to finish, what's the typical time: _____________

Q7. How important is this process to the organization and project?

Q8. Is there a lot at stake in how well this process works?

Q9. In this location, how many people are involved? Can you list the different jobs (or roles)? For example, in a restaurant, there might be a hostess, waiter, busboy, cook, cashier…)

Q10. For each of those jobs or roles, how many different individuals would you say are involved in doing this routine in your organization? For example, 2 hostesses, 12 waiters…

Q11. In how many different locations is this process performed?

PART 2: Break the process down into steps

Now I'd like to break this process down into steps. There may be quite a few steps, so we may need to go slowly. I appreciate your patience.

Q12. First, let's pin down the start and the finish

Q12a. What happens FIRST? How do you know the process has started?

Q12b. What happens LAST? How do you know it has ended?

Q13. Now talk me through again, but let's go a little slower so I can write down each step. As we go, try to think of "what happens next?" Once we've got the list, we'll go through it again and I'll ask if that *always* happens next, or if there are special cases, alternatives or exceptions.

PART 3: Identify the sequence of steps

Now let's go through it again and focus on sequence. And if I left out any steps, we can add those in.

Q14. Starting with the first action, **what happens next**?

Q15. Is that always what happens, or are there alternatives or exceptions? If there is an alternative, let's not worry about how often it happens. Right now, I want to know if it's possible for the sequence to go another way or not.

PART 4: Estimate the frequency of alternatives or exceptions

Q16. Now let's go through this one last time and focus on how *often* different alternatives happen. For each place where there is an alternative or exception, I'm going to ask you to estimate how often that happens. Try to make your best guess. [Prompt with: 90-10? 80-20? 60-40? 50-50?]

PART 5: VR/Enscape and the process

In relation to the steps and sequence of the process:

Q17. At what point in the process was/is VR/Enscape introduced?

Q18. How was it introduced into the process?

- Q18a. How did you use VR/Enscape?

Q19. When was it introduced into the process?

Q20. If so, can you tell some good and/or bad stories of the use of VR for client communication and collaboration?

- Why good or bad experiences?

Q21. Did VR/Enscape change how you would normally work with the client/collaborator/us

Field notes

Template

Time and Date: • If written after observation, date not noted or page created before/after observation	
What is being observed? • Project, • Routine, • Activity	
Descriptive information • Who, what, when, where, why, how • Specific facts: numbers, details etc.? • Sensory impressions? • Insider language?	**Who, what, when, where, why, how**
Reflective information • Reflection on the day's experience • How did I impact the situation?	
Emerging Questions/Analysis • Potential lines of insights, • Useful theories? • Further investigations?	
Document, File etc. • Something that documents what you observed	

Example

Time and Date: • If written after observation, date not noted or page created before/after observation	

What is being observed? • Project, • Routine, • Activity	Design routine. Project A. Collision checking in 3D (Enscape).
Descriptive information • Who, what, when, where, why, how • Specific facts: numbers, details etc.? • Sensory impressions? • Insider language?	**Who,** Peter - a construction engineer **what,** Talked about the difference between using Enscape (a program that allows one to walk/fly through a 3D model) **when,** When going and talking to him about a future meeting. **where,** at the office, at his desk. **why,** He was using Enscape to control a 3D modelled house for collisions - just as he did during the interview the day before. **How** He used Enscape to walk through the house. He was sitting at his computer which has two monitors. On one of the monitors he had ArchiCAD open (showing a 2D plan drawing of the house) and on the other he had Enscape open showing a 3D rendered view of the house. When I walked up to him, to ask about something with regards to a future meeting I noticed he was using Enscape and remarked it. Next I also asked why he didn't use VR-goggles when doing this collision checking. He answered that the most important thing is to be able to quickly see the rendering in 3D and be able to walk through it. He then remarked that he could just as well see the rendering on the monitor and added that the most important thing is to be able to quickly render the house, which Enscape enables (because Enscape use the graphic card instead of the CPU = quicker renderings) which in turn enabled him to quickly determine errors in the ventilation system that another engineer, with which they corporate, had incorporated into the model.
Reflective information • Reflection on the day's experience • How did I impact the situation?	I had an impact on the situation as I walked to his desk and asked him thus making him aware of his current work - however, it didn't seem like this impact was significant.
Emerging Questions/Analysis • Potential lines of insights, • Useful theories? • Further investigations?	I think for professionals, that are used to look at 2D drawings the VR-goggles are not THAT important for their work routines, because they are accustomed to interpret the scale of rooms and for that, watching a 3D model on the screen, is good enough. At least, it seemed that it wasn't worth the effort in this case also because he had to look at the other screen as well to constantly check the 2D drawing. If he had used the VR-goggles he would have to take them on and off. In addition, the VR-goggles were located at another table 5 meters away from him which meant that he would have to walk over to the headset and copy the file to the VR-laptop. Or attach his headset to his computer, calibrate the controls, and set up the sensors.
Document, File etc. • Something that documents what you observed	

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