

# Shared Situation Awareness in Student Group Work When Using Immersive Technology

An observational study

Tabea Bröring

Department of Computer  
and Systems Sciences

Degree project 30 credits  
Computer and Systems Sciences  
Degree project at the master level  
Spring term 2023  
Supervisor: Johan Stymne





# Abstract

Situation awareness (SA) describes how well a person perceives and understands their environment and the situation that they are in. When working in groups, shared SA describes how similarly the team members view and interpret the situation in a given environment. Immersive technology comprises technology that integrates virtual objects into the user's reality of a physical world. It holds great potential for the application in educational contexts and collaborative settings like group projects. Immersive technology can increase engagement, make complex concepts more tangible, and increase media fluency. When immersive technology is introduced into a real-world setting, it creates a mixed reality with virtual and physical elements. In mixed reality collaborations, the complexity of elements in the environment can negatively affect the shared SA of the group members. The research problem of this thesis is that the intersection between shared SA and student group work that involves immersive technology is under-researched to this date. The research question is "How is shared situation awareness in student group work formed when using immersive technology?". A case study of a student group containing a participatory observation of several of their work sessions was carried out, and the obtained material was analyzed using sequential analysis. It was found that the students do not prioritize shared SA but work individually, dividing smaller subtasks among themselves and focusing on their own tasks first and foremost. Communication is used sparsely to stay updated about the other students' work status, which helps to build shared SA. Communication also plays a crucial role in building shared SA when using immersive technology. It was also observed that the students prefer to use immersive technology in a way that allows more than one person to see the same virtual environment, as it is the case when two virtual reality (VR) headsets are connected to the same application.

*Keywords:* shared situation awareness, situation awareness, immersive technology, mixed reality, virtual reality

# Synopsis

## Background

Situation awareness (SA) is a concept that describes how well a person perceives and understands their surrounding environment and the current situation that they are in. SA depends on individual factors, such as a person's prior experience and information processing abilities, and system factors, such as the complexity of the environment. When working in groups, shared SA describes how similarly the team members view and interpret the situation and the environment. Immersive technology is highly sought after for its application in educational contexts. It holds the potential to increase learner engagement, make complex concepts more tangible and, therefore, easier to understand, and increase media fluency. When immersive technology is introduced into a real-world setting, it creates a mixed reality (MR) with virtual and physical elements. In MR collaborations, the complexity of elements in the environment can negatively affect the shared SA of the group members. This study belongs to the human-computer interaction area within computer and systems science.

## Problem

The intersection between shared SA and student group work that involves immersive technology is under-researched to this date. Researching the formation of shared SA in this context can make student group work with immersive technology more effective.

## Research Question

The research question that this thesis contributes to answering is "How is shared situation awareness in student group work formed when using immersive technology?". This study intends to find methods of how a student group forms shared SA, which are interesting findings that help to understand and improve how social interactions and technological devices can facilitate the formation of shared SA in group work. It relates to the research problem by contributing to filling the discovered knowledge gap.

## Method

The research strategy of a case study is applied. One particular instance of student group work is investigated in great detail. The data collection method used is observation. One student group working on a group project for the course "Design for Complex and Dynamic Contexts" is observed over several of their work sessions. For analysis purposes, the sessions are recorded using a smartphone camera. The video is used to perform the data analysis which is a sequential analysis of the groups' interactions using a behavior coding scheme that is developed for this study. As a result, behavioral patterns are discovered that serve as the basis for analysis.

## Result

The data analysis revealed that communication plays a crucial role in building shared SA. The students inform themselves about the work status of another student by openly and directly asking the other student. When using immersive technology, the students would speak about what they are seeing in the virtual environment, communicate their goals, and ask for and give advice to each other. It was also observed that the students seek to use the immersive technology in a way that allows more than one person to see the same virtual environment. They implement this by handing over the VR headset or working in a mode where they can use two headsets and connect them to the same lobby so that they can enter the same virtual space and see the same elements at the same time. However, shared SA is not prioritized by the students. Instead, they work in an individual way where they divide smaller subtasks among themselves and focus on their own tasks.

## Discussion

Due to the exploratory nature of the thesis, this study gives an overview of the most eminent aspects of the shared SA of a student group that is working with immersive technology. The discovered behavioral patterns introduce novel and original findings about the formation of shared SA in student group work with immersive technology. A limitation of the study is the potential bias that is introduced by the coding of the observation protocol which was done by the researcher alone without a second person to confirm the consistency and correctness. For future research, it would be interesting to broaden the study subjects to groups other than university students, such as pupils or employees. By applying research methods that allow to obtain objective measures of SA, the hypotheses from this study could be tested, and the effect of different designs of immersive technology on SA could be quantitatively assessed.

# Acknowledgement

I want to say thank you to my supervisor Johan Stymne for his patience with me and the valuable feedback he provided throughout our meetings. His constructive way of asking questions always gave my Master's thesis a new direction and widened my view on the topic.

I also wish to thank my fellow students for the peer reviews that I received. They always gave valuable insights and helped me make my thesis more understandable.

The student group which allowed me to observe them during their work have made the whole project possible and I am deeply grateful to them. Their cooperation and natural way of carrying on with their work made for a good data quality and it was a pleasure to work with them.

Finally, I want to thank my friends and family for proofreading, motivating, and supporting me throughout this challenging project.

Thank you to all of you for guiding, challenging, and motivating me. This thesis would not have been possible without your help.

# Contents

<b>List of Figures</b>	<b>iii</b>
<b>List of Tables</b>	<b>iv</b>
<b>List of Abbreviations</b>	<b>1</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Problem . . . . .	2
1.2 Research Question . . . . .	2
1.3 Thesis Structure . . . . .	2
<b>2 Background</b>	<b>3</b>
2.1 Situation Awareness . . . . .	3
2.2 Immersive Technology . . . . .	6
2.3 Mixed Reality Collaboration in Education . . . . .	7
<b>3 Methodology</b>	<b>9</b>
3.1 Research Strategy . . . . .	9
3.2 Research method . . . . .	10
3.3 Participants . . . . .	11
3.4 Data Analysis Method . . . . .	12
3.5 Ethical Aspect . . . . .	15
<b>4 Results</b>	<b>16</b>
4.1 Observation Protocol . . . . .	16
4.2 Work Setting . . . . .	16
4.3 Data Analysis . . . . .	17
<b>5 Discussion</b>	<b>24</b>
5.1 Priority of Shared Situation Awareness . . . . .	24
5.2 Communication . . . . .	25
5.3 Use of Immersive Technology . . . . .	26
5.4 Ethical and societal consequences . . . . .	28

<b>6 Conclusion</b>	<b>29</b>
6.1 Limitations . . . . .	29
6.2 Future research . . . . .	30
 <b>Bibliography</b>	 <b>34</b>
 <b>Appendices</b>	 <b>35</b>
<b>A Informed Consent Form</b>	<b>35</b>



# List of Figures

2.1	Model of SA Formation adapted from Bolstad et al. (2005) . . .	4
2.2	Virtuality Continuum adapted from Milgram and Kishino (1994)	6
4.1	Behavioral Pattern during Single use of Headset with no increased Communication . . . . .	18
4.2	Behavioral Pattern during Single use of Headset with increased Communication . . . . .	19
4.3	Students Working in a Shared Lobby . . . . .	20
4.4	Behavioral Pattern during Shared use in Same Lobby of Headset	20
4.5	Behavioral Pattern during Hand over of Headset . . . . .	22
5.1	Students Working Individually . . . . .	25

# List of Tables

3.1	Behavior coding scheme for collaboration with immersive technology as seen in Biehl et al. (2007)	13
3.2	Behavior Coding Scheme	14
4.1	Observation Protocol Excerpt - S5 involvement	17
4.2	Observation Protocol Excerpt - Headset Single Use with no increased Communication	18
4.3	Observation Protocol Excerpt - Headset Single use with increased Communication	19
4.4	Observation Protocol Excerpt - Headset Shared use in same Lobby	21
4.5	Observation Protocol Excerpt - Headset Hand over	23

# List of Abbreviations

**AR** augmented reality

**AV** augmented virtuality

**MR** mixed reality

**SA** Situation awareness

**VR** virtual reality

# Chapter 1

## Introduction

Thanks to its many affordances, group work is recognized as a highly useful working mode for projects in university contexts (Fearon et al., 2012). The combined knowledge and resources of the group members, the resulting heightened problem-solving abilities, and the chance for all group members to improve their interpersonal skills are all advantages of group work that make it such a popular element of learning practice (Burke, 2011). At the same time, the emergence and continuous improvement of immersive technology such as VR, augmented reality (AR), and tangible technology cause it to be employed in many different domains such as marketing, entertainment, production, healthcare, and education (Suh & Prophet, 2018). Immersive technology is also being introduced to collaborative settings to leverage its visualization, interaction, and control mechanisms (de Belen et al., 2019; Nguyen et al., 2016; Salimian, 2015). With this addition, group work takes place in a mixed-reality where elements of the physical world as well as the virtual elements introduced by immersive technology are present (Salimian, 2015). While the concept of immersion, which expresses that the user feels physically and psychologically invested in the created virtual space (Berkman & Akan, 2019), is usually deemed a desirable characteristic for the individual use of immersive technology (Suh & Prophet, 2018), it raises the question of how well this immersion can be combined with the setting of group work. A high degree of immersion is achieved by addressing many of the user's senses through various stimuli (Berkman & Akan, 2019). However, performing a collaborative task in a group requires communication and attention toward the collaborators and the surroundings as well. This aspect is covered by the concept of shared SA. SA describes to what extent a person can perceive elements in their environment, comprehend them, and is able to predict their status in the future (Endsley, 1995). Shared SA extends the concept to describe how similarly members of a group view and understand a given situation and in group work constellations, the shared SA is, among other factors, a determining factor for the group's performance (Bolstad et al., 2005).

Looking at previous literature, it becomes apparent that much research has been conducted in the field of immersive technology in education already. However,

it is often focused on the transfer of knowledge and affective experiences from a designated teacher to their students. Little attention has been paid to peer-to-peer interaction (Suh & Prophet, 2018) such as student group work. The topic of SA research is historically interwoven with the use of technology since it originated in the aviation industry (Endsley, 2012) where displays and controls are omnipresent and research in this field prevails to this date (Yiu et al., 2022). There is also literature on shared SA in technology-rich environments like human-robot collaboration (Sonawani & Amor, 2022; Tabrez et al., 2022) and autonomous driving (Narri et al., 2021). The influence of immersive technology on shared SA has been addressed in research (Salimian, 2015), and the topic of SA in collaborative environments is reflected in studies as well (Kulyk et al., 2008). In conclusion, it can be seen that prior research extensively explored the topics of shared SA in collaborative settings as well as shared SA paired with immersive technology applications. Immersive technology in education and group work has also been examined before. Nevertheless, the intersection between the three research fields, SA, student group work, and immersive technology, has not received much attention to this date. This study aims to contribute to the knowledge base by conducting an observation of a student group that is working with immersive technology.

## **1.1 Problem**

The problem that this thesis addresses is that the intersection between shared SA and student group work that involves immersive technology is under-researched to this date. Thus, this thesis intends to contribute to filling the research gap existing about shared SA in student group work when integrating immersive technology.

## **1.2 Research Question**

The research question that this thesis will strive to answer is "How is shared situation awareness in student group work formed when using immersive technology?"

## **1.3 Thesis Structure**

This thesis will discuss relevant background knowledge from literature in chapter 2 and introduce and argue for the chosen research strategy and method in chapter 3. Results from the data collection will be presented in chapter 4 before they are discussed in chapter 5. Finally, conclusions can be found in chapter 6.

## Chapter 2

# Background

### 2.1 Situation Awareness

Situation awareness (SA) is a concept that originated in the field of aviation, and it is understood as "an internalized mental model of the current state of the operator's environment" (Endsley, 2012, p.553). Endsley (1995) describes three levels of SA: The first level is perceiving the elements in one's surroundings, which also involves their state, relevant characteristics, and relation to other elements. On the second level, the situation needs to be understood. The perceived elements have to be put into context, and their significance has to be assessed to form a holistic picture of the ongoing situation. On the third level, the operator can project the situation's status in the future, which is critical for decision-making according to the operator's goals. SA can only be built and sustained when a person's attention is sufficiently available and directed towards important elements (Endsley, 2012). The degree of SA that an operator has is influenced by system factors, such as the complexity of an environment, interface design, and stress, and individual factors, such as experience, abilities they possess, and information processing capabilities (Endsley, 2012). Kulyk et al. (2008) identified the risk of lowering the SA when a person is exposed to too much visual information in the form of technological displays. This is highly relevant for the motivation of the research question that this study poses, namely, how shared SA can be formed in a student group work scenario when immersive technology, and therefore another technological device, is introduced into the work setting. As SA can only be built and sustained when sufficient attention is allocated to the processes and data of interest (Endsley, 1995), exposing a person to a technological environment with a large amount of information may exceed their capacity for perceiving and interpreting the situation. At the same time, the study by Biehl et al. (2007) suggests that technology can help reduce the complexity of an environment by consolidating information coming from multiple sources into one medium such as a display to decrease the attentional demands. Technology can therefore serve as both, an amplifier or attenuator

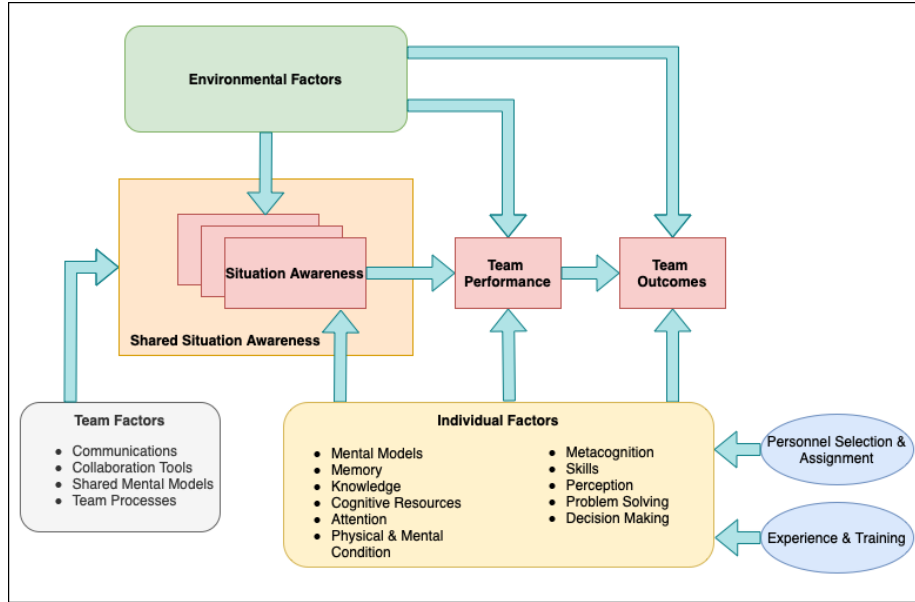


Figure 2.1: Model of SA Formation adapted from Bolstad et al. (2005)

for regulating the complexity of the environment.

There are several proposed ways of measuring SA in literature. One can either have subjective assessments that the research subjects give about themselves or objective measures obtained by asking task-related questions and scoring the SA on the basis of the number of correct answers (Salmon et al., 2009). As measuring SA is not the focus of this thesis, the measurement methods will not be presented in more detail.

Bolstad et al. (2005) continued to extend the definition for individual SA from Endsley (1995) to groups when defining shared SA as "a reflection of how similarly team members view a given situation" (Bolstad et al., 2005, p.1). The factors determining SA in group work are presented in the model from Bolstad et al. (2005) (see figure 2.1). This study builds upon the model as the basis for understanding how the formation of shared SA takes place, which makes the article of Bolstad et al. (2005) one of the most important foundations of this work. In the model, the individual factors and the environmental factors remain similar to the ones that Endsley (1995) describes for SA. Experience and training as well as personnel selection and assignment to tasks can have an influence on the individual factors of the team (Bolstad et al., 2005). In addition to this, team factors such as communication and shared mental models are introduced (Bolstad et al., 2005). They have an effect on the shared SA which is made up of each team member's individual SA and the extent to which they overlap to form a common understanding of the situation (Schei & Giske, 2020).

Shared SA is researched in diverse contexts. Shared SA is investigated in pro-

fessional team sports due to the correlation between shared SA and team performance (Schei & Giske, 2020). Especially the importance of shared mental models is highlighted in this research field (Schei & Giske, 2020). The shared mental model is represented by a coach master plan in team sports and it is important for the players to have shared knowledge in order to understand a given situation in a game in the same way, and interpret the coach’s cues in a similar matter (Schei & Giske, 2020). Bolstad et al. (2005) used data from military training to build a model for the formation of shared SA as already discussed. The authors highlight the importance of shared SA devices which include shared technology like displays as well as communication and a common environment where details need not be communicated but can be physically seen by all members at the same time. The field of shared SA in aviation, where the concept of SA originated, is still researched to this date as the work of Yiu et al. (2022) on cooperation between flight crews under bad weather conditions proves. Another example of shared SA in a critical application field is the application in disaster management where multiple organisations have to work together to respond to an environmental disaster (Laurila-Pant et al., 2023). Laurila-Pant et al. (2023) propose a framework that specifically includes shared SA for decision-making processes in disaster response. Accumulating and sharing data via information systems and communication among individuals and organisations result in the formation of shared mental models and therefore the increase of shared SA which enables the involved parties to coordinate their efforts (Laurila-Pant et al., 2023). Similar to this, a study about shared SA across cyber security centres acknowledges the importance of sharing insights and analytics to form a shared understanding of the situation and appropriate responses (Fysarakis et al., 2022). Bunker (2020) points towards the risks of digital destruction, namely fake news and the infodemic, on the shared SA of society. This creates dissonant mental models through the differing information basis that each individual is provided, which in turn hinders the formation of shared SA (Bunker, 2020). Shared SA is of interest in human-robot collaboration as well (Sonawani & Amor, 2022; Tabrez et al., 2022). Tabrez et al. (2022) aim to improve communication between the robot and the human through showing visual guidance cues from the robot that are displayed on an augmented reality (AR) interface. The robot can develop comprehensive probability models that may help the human in their decision making process, but to reap this advantage, both parties need to have access to the relevant information which is facilitated through making the robot’s models visible through the visual guidance cues (Tabrez et al., 2022). Sonawani and Amor (2022) work towards enabling communication between a robot and a human through visual cues as well. The authors propose a framework for intention projection which visualizes the upcoming actions of the robot through a mixed reality (MR) interface to share this information with the human (Sonawani & Amor, 2022). This further underpins the importance communication and information sharing for all involved parties to have a shared understanding of the situation at hand. The concept of shared SA is even applied to the collaboration between technological entities as well, as it can be seen in the study done by Narri et al. (2021) on shared SA in automated vehicles.



It is crucial for safe autonomous driving that the vehicles perceive and understand their environment well (Narri et al., 2021). Instead of the vehicle being constraint to only perceiving a situation through sensors in the vehicle itself, the approach that this study applies incorporates data from various sensors in the environment of a vehicle to increase the SA of the individual vehicle and by sharing this information with other vehicles, it in turn increases the shared SA across all automated vehicles in proximity (Narri et al., 2021).

All of the above mentioned literature relates to this study in the way that it already puts forward discovered methods of shared SA building in different contexts. As elaborated above, the topic of shared SA has been researched in many application fields like aviation, professional team sports, disaster management, human-robot collaboration, and autonomous driving with a focus on the methods that facilitate the formation of shared SA. However, there is no previous research on the formation of shared SA in the application field of collaboration in education with the use of immersive technology, which is the focus of this study.

## 2.2 Immersive Technology

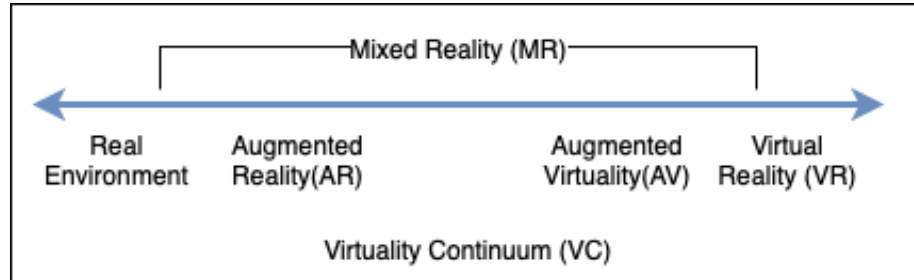


Figure 2.2: Virtuality Continuum adapted from Milgram and Kishino (1994)

Immersive technology has been defined in different ways over the last few years. Soliman et al. (2017) describe it as technology that achieves to make the virtual world seem real through immersion. Milgram and Kishino (1994) found that there are different degrees of virtuality and introduced the concept of the virtuality continuum. It spans between a purely real environment with only physical objects and a purely virtual environment. Everything that lays between those two extremes is called MR (de Belen et al., 2019; Milgram & Kishino, 1994). A graphical representation of this can be seen in figure 2.2.

Examples of immersive technology can be found in VR applications, AR applications, and augmented virtuality (AV) applications (de Belen et al., 2019). VR enables the user of the technology to move and interact within a purely virtual world (Suh & Prophet, 2018). In AR, virtual objects are inserted into the real

world for the user to interact with using a mediating technology (H. Y. Chang et al., 2016). AV places physical objects in an otherwise virtual environment (de Belen et al., 2019).

Two important concepts in immersive technology are the concept of presence and immersion (Berkman & Akan, 2019). Presence expresses the user’s subjective feeling of being actually “there” in a non-real environment whereas immersion describes the extent to which the user feels engaged in a virtual environment, and it is firmly tied to the sensory stimuli that are experienced when using immersive technology (Berkman & Akan, 2019).

The most common domains where immersive technology is used are education, healthcare, and entertainment (Suh & Prophet, 2018). Especially in the gaming sector, the effects of employing more immersive elements are studied intensively because the affordances are very promising. Brondi et al. (2015) clearly outline that a high degree of immersion in games can enhance player engagement and the flow experience, but it also negatively affects the player’s performance in their experiment. They accounted for the decline in performance to the unfamiliarity of the participants with the immersive technology (Brondi et al., 2015). In the healthcare sector, immersive technology can be applied in various psychological and physiological therapy approaches because it holds the potential to alleviate stress, anxiety, and physical pain in patients (Suh & Prophet, 2018). For educational purposes, it has been found that especially AR can help to enhance learning experiences by engaging students with objects that are not accessible under normal circumstances but can be perceived in a matter that feels real to students through technology (H. Y. Chang et al., 2016). Immersive technology can heighten engagement of learners, has a positive influence on learning outcomes, and affords a sense of connectedness to learners when they approach a task together (H. Y. Chang et al., 2016). This also helps to have the learner associate positive feelings with the learning contents and activity (Suh & Prophet, 2018).

As shown above, previous research on immersive technology can be found in application fields like gaming, healthcare, and education and focuses mostly on the effect of using immersive technology on the individual. As this study is placed in an educational context as well, the existing literature on this topic is of interest. However, previous research in this field is more centered around the individual use of immersive technology by pupils or student whereas this study focuses on the effect of immersive technology use on the dynamics of group work done by students. Therefore, the findings of previous research are important to understand why immersive technology with its affordances is applied in education but have little overlap with what this study analyses.

## 2.3 Mixed Reality Collaboration in Education

When immersive technology is introduced into a collaborative work setting, it adds virtual elements to the real world and thus places the work in MR (Suh & Prophet, 2018). Distinctions that are being made when talking about MR

collaboration are between the temporal and the spatial dimensions. When users are in the same location, the collaboration is collocated; when they are in different places, it is remote; and a mix of both is called a variable setup (de Belen et al., 2019). Regarding the temporal mode of interacting, there are synchronous collaborations, where users work at the same time, and asynchronous collaborations, where users work at different times (de Belen et al., 2019).

A systematic review that de Belen et al. (2019) carried out for papers on MR collaboration published between 2013 and 2018 revealed that nearly 30% of all studies were conducted in the application area of education and training and almost all of them were done in collocated setups. Through MR collaboration, students can learn together, and elements like gamification enhance the students' engagement (de Belen et al., 2019). Group work in higher education is particularly used for granting students a social learning experience with which they are able to develop the knowledge and high-order cognitive skills needed for the practice in the working world (Fearon et al., 2012). These skills include the ability to negotiate with fellow students, network in terms of building social relationships, and navigate conflicts and inspire motivation within the group (Fearon et al., 2012). The collective problem-solving process also helps students to feel a higher degree of ownership of the solution and their learning outcomes (Fearon et al., 2012).

Kulyk et al. (2008) identified different features that should be available when introducing technology to a collaborative setting. To ensure a positive effect of the applied collaboration technology towards the interaction in group work the technology should have a highlighting function for the speaker to direct the focus of the group to a certain visual in a shared artifact (Kulyk et al., 2008). Moreover, an activity history for commonly used artifacts can be stored and visualized to facilitate the work with multiple people on one object (Kulyk et al., 2008).

As elaborated above, previous research on MR collaboration has been done with a focus on learning and engagement, which does not match the focus of this study of how the use of immersive technology affects the formation of shared SA in group work. The study of Kulyk et al. (2008), however, serves as one of the most important scientific articles that this thesis builds upon since their research aim of providing technological support for the formation of SA in a collaborative environment is very close to the topic of this thesis. Their findings are therefore compared and discussed in relation to the findings of this study and the same research method has been applied to this study as well.

## Chapter 3

# Methodology

### 3.1 Research Strategy

To answer the research question of "How is shared SA in student group work formed when using immersive technology?", a qualitative research approach is chosen. The applied research strategy must allow the researcher to investigate the topic of shared SA in student group work on a holistic level, as there is no previous research that points towards a specific factor that should be investigated. The strategy of a case study fits this requirement very well and is chosen for this study. A case study focuses on one distinct instance of what should be investigated (Denscombe, 2010) - in this case a student group work. This instance occurs naturally, which means that it already exists and is not artificially created, as it is the case in an experiment. A case study intends to discover knowledge from deeply researching one particular case to draw implications for the general (Denscombe, 2010). By focusing on one case only, more time and attention to detail can be spent on that instance which can uncover more unique and subtle insights (Denscombe, 2010). A case study is, therefore, well fit to be used in social research as the complex relationships and processes can be treated with the proper attentiveness (Denscombe, 2010).

An alternative research strategy that could have been used for this research is to conduct an experiment. Several studies use this approach to assess shared SA in collaborative settings with the support of technology (Biehl et al., 2007; Chen & Hwang, 2017; Kulyk et al., 2008; Yiu et al., 2022). The advantage with this research approach is that by creating a controlled setting, as it is the case with experiments (Denscombe, 2010), it is possible to obtain measures of the shared SA in collaborated settings. The studies from Biehl et al. (2007) and Kulyk et al. (2008) put a focus on evaluating the efficacy of their proposed technological solutions in regard to shared SA. The study of Yiu et al. (2022) compares the efficacy of different communication protocols in regard to the shared SA. For these specific purposes, it is a fitting approach to choose an experimental setup that allows for taking measurements of the shared SA. The reason that the

experiment as a research strategy was rejected for this study is that measuring the degree of shared SA is not the focus of this study. Instead, observing the realistic dynamic of student group work in a naturalistic setting of a case study fits the exploratory approach better.

## 3.2 Research method

As the objective is to investigate shared SA in a real-life group work situation, the research method of observation is chosen. The study of Biehl et al. (2007) on awareness in software development teams is thematically close to this study and uses an observational approach as well. A scoping review done by Al-Moteri et al. (2022) on research of shared SA in the hospital emergency context found that seven out of eight studies applied an observational design as well. Despite the context being different to this study, the affordances of observation as a research method for studying shared SA, that will be outlined below, motivate why observation is fitting well.

Denscombe (2010) outlines two types of observation in scientific research: the systematic observation and the participant observation. Systematic observation tends to produce quantitative data that is useful for statistical analysis. Observation is highly dependant on the researcher because people’s perception rely on their past experiences, familiarities, and their current emotional and physical constitution (Denscombe, 2010). Systematic observation attempts to counter this by predefining what should be observed by creating an observation schedule beforehand which eliminates variations in the results and produces more robust results (Denscombe, 2010). In contrast to this, participant observation rather yields qualitative data (Denscombe, 2010). Here, the researcher integrates themselves into the situations to collect detailed information about the research subjects (Denscombe, 2010). Participant observation is mainly used in anthropology and sociology, and the researcher should try to not disrupt the natural occurrence of events by making the subjects feel observed (Denscombe, 2010). The researcher takes an active role in this method by joining the subjects in their activities and considerable time should be spent in a setting to obtain a holistic picture of the research subject (Denscombe, 2010).

As this study intends to collect qualitative data, the observation approach of participative observation is chosen. The researcher is present in the student group work over several sessions and discloses their role to the research subjects. Thus, the researcher’s influence on them cannot be excluded completely. Mundane situations are observed, in this case, a collaboration between fellow students. Particular attention is paid towards having as little intervention from the researcher as possible to preserve as much naturalness as possible. For this reason, the researcher never interferes in the group activity, holds themselves in the background of the room taking notes, and installs a smartphone for recording the group work. This includes video and audio recordings. To ensure that the observation is consistent and reliable, a framework is used which is implemented by drawing up an observation protocol. Since there are video recordings of the

sessions, only a preliminary observation protocol was set up beforehand to capture communication - and interaction aspects during observation. The material was then rewatched under different viewpoints as many times as required to redesign and complete the observation protocol.

This study has an exploratory approach as the research question calls for discovering methods of forming shared SA in a, to this date, under-researched area. As Denscombe (2010) states, observation as a research method offers the opportunity to do fieldwork research and directly observe what is happening rather than relying on the participants' assessment of a situation. This is fitting the research approach of this study as behavioral patterns should be discovered, and those are only partly aware to the person exhibiting them.

An alternative research method for this study could have been to conduct interviews with the students who participate in the group work. Interviews are a method of collecting data directly from the research subjects by asking questions about the topics of interest (Denscombe, 2010). By giving the participants the chance to speak for themselves, it is possible to collect insights into their emotions, opinions, and experiences from a highly subjective perspective (Denscombe, 2010). This holds a clear advantage over methods such as observations and documents research as the otherwise invisible (or only hardly observable) aspects inside a person can be made explicit (Denscombe, 2010). Conducting interviews in addition to using other data collection methods is common practice in case studies to reap the before mentioned advantages of subjective insight into the research participants. Looking at the measurement techniques of shared SA in previous research, it becomes apparent that letting the operators of an experimental SA testing simulation rate aspects of their perceived SA or asking them about environmental details is a major part of determining the level of shared SA (Endsley, 2020; Salmon et al., 2009). The questions asked in order to measure shared SA can be regarded as a very standardized, structured form of interviewing the research subjects. The reason why this research method has been rejected is that the research area of SA in student group work with the use of immersive technology is largely untouched, and measuring the SA is not the goal of this study but rather a matter for future research. This research, with its exploratory approach, profits more from a holistic method that reveals patterns in behavior that are visible from an objective observer perspective.

### 3.3 Participants

The participants that are being observed are students of the master's program "Design for Creative and Immersive Technology" at Stockholm University. The course "Design for Complex and Dynamic Contexts" includes a group project in which the students need to develop a prototype of an immersive technology application, and it, therefore, qualifies for observing group work with immersive technology. The observed collaboration type can be described as a collocated, synchronous collaboration.

Purposive sampling is utilized to specifically select a group of students that

teamed up to perform the group work portion of the course and agree for their meetings to be recorded. The advantage of this is that a group of people who are most likely to provide the sought-after information can be selected, and it fits the exploratory character of this research (Denscombe, 2010). Denscombe (2010) establishes that small numbers of research samples are suitable for exploratory studies because each person in the sample can be studied in considerable depth, and the biggest asset of exploratory samples is the informative character rather than the accuracy of the results. An alternative sampling method that could have been used is theoretical sampling, where the researcher chooses the instances for data collection in stages, meaning that the researcher starts working on a theory with a first sample and then selects further samples that supply new evidence for the theory (Denscombe, 2010). The advantage with this method is that the researcher can purposefully select new people and events of interest to research without having to continue with the first chosen sample (Denscombe, 2010). Due to the limited time available for the data collection, this sampling method was rejected and instead considerable effort was spent on finding a suitable student group with purposive sampling. The selected group of students is observed in different sessions over the course of one week. Each session is filmed with a smartphone, which should feel relatively normal and unobtrusive to the students as opposed to a more complex setup with multiple bigger video cameras. Before each session, the students are informed about the purpose and the procedure of the observation, and their consent is obtained (see appendix for the informed consent form).

### 3.4 Data Analysis Method

The obtained data from the sessions are in the form of video recordings of the group meetings. A sequential analysis with the intention of discovering behavioral patterns is performed to generate knowledge pertaining to the research question from the data. The same data analysis technique is used in the study from K.-E. Chang et al. (2014) about the impact of AR on the learning of art museum visitors, which, despite the different context, researches the effect of immersive technology on humans behavior, similar to this study.

According to Bakeman and Gottman (1997), analyzing how events follow each other can “[offer] the best chance for illuminating dynamic processes of social interaction” (Bakeman & Gottman, 1997, p.1). The first step to performing a sequential analysis is to familiarize oneself with the data and design a coding scheme that reflects the different interactions in the observation material well (Bakeman & Gottman, 1997). Although Bakeman and Gottman (1997) advises against using a coding scheme from another scientist’s research, the literature research revealed a very similar observation analysis that serves as a starting point for creating the coding scheme of this work. This coding scheme comes from Biehl et al. (2007), who created a coding scheme that categorizes group behavior while using collaborative software and hardware products (see table 3.1). This scheme needs some adaptation to this specific use case of immersive

Category	Classification
Communication	Advice/instructional
	Agreement
	Collaboration request
	Disagreement
	Information/bottleneck
	Orientation/understand
	Status
	Other
Shared display use	Load information
	Connect device
	Transfer control
	Visual scan
Shared physical artifact use	Create
	Modify/update
	Deictic reference
Collaboration type	Co-located with shared visual workplace
	Co-located without shared visual workplace
	Distributed
Collaboration configuration	Multiple personal devices
	Single device, single control
	Single device, shared control
	Shared display only
	Shared and personal devices used

Table 3.1: Behavior coding scheme for collaboration with immersive technology as seen in Biehl et al. (2007)

technology in student group work, e.g. there is no distributed collaboration. However, it serves as a good basis for capturing different social interactions as well as the use of technology. The authors themselves claim that "this coding scheme [...] can be re-used in subsequent field studies that seek to learn more about how co-located users collaborate within a technology-rich workspace" (Biehl et al., 2007, p.1318). After carefully studying the recorded sessions, the category "Shared physical artifact use" was deleted since the physical artifacts in the room, such as whiteboards and sticky notes, were not used during the sessions. The "Collaboration type" category was also rejected since the group was constantly collocated and did not change. In the category "Communication", the classifications "Disagreement" and "Bottleneck" were deleted because they did not occur in the observation. The category "Shared display use" was changed to "Headset use" to correctly document the technological conditions under which the sessions took place. Furthermore, the use of immersive technology is the focus of this study and as such it should be included when coding the behavior of the group work. Lastly, the classifications in the category "Collaboration configuration" were adapted to reflect the student group work setup



with the classifications "Use multiple personal devices", "Use single device with another person observing", and "Person takes over another one's device". The resulting adapted coding scheme can be seen in table 3.2.

In the next step of the sequential analysis, the coding scheme is used to create

Category	Classification
Communication	Advice/Instruction
	Agreement
	Collaboration request
	Information
	Orientation/Understand
	Status
	Other
Collaboration Setting	Use multiple personal devices
	Use single device with another person observing
	Person takes over another one's device
Headset Use	Single use
	Shared use in same lobby
	Hand over

Table 3.2: Behavior Coding Scheme

a protocol for what was observed. All observations are classified and documented, ideally with additional information about the time dimension (Bakeman & Gottman, 1997). This study focuses on the events that relate to social interactions and the use of technology and provides timecodes for the start of each event. After coding the recorded sessions, sequences of events can be modeled to discover and visualize behavioral patterns (Bakeman & Gottman, 1997). These should give insight into how shared SA can be formed in student group work when using immersive technology.

An alternative data analysis method is the descriptive statistics approach within the sequential analysis which presents data such as frequencies of occurring events, percentages of the occurrence of specific events in relation to all events, or mean event durations as a result of the observation (Bakeman & Gottman, 1997). It has the advantage of conveying straight-forward, quantitative data about the observation to the reader (Bakeman & Gottman, 1997). However, this data analysis method has been rejected in favor of the modeling approach within sequential analysis that generates behavioral patterns because the descriptive statistics as a quantitative analysis method does not fit the qualitative nature of this study as well as the modeling approach.

### 3.5 Ethical Aspect

When conducting a scientific study, ethical aspects must be considered. Denscombe (2010) presents four key principles in research ethics:

1. Protecting the interests of the participants
2. Ensuring participation to be voluntary with informed consent
3. Scientific integrity and avoidance of deception
4. Compliance with the law

To ensure that the interests of the participants are protected, the researcher should prevent safety threats to the participants and treat the given information as confidential. The participants' anonymity should be kept unless their consent for disclosure is explicitly given. (Denscombe, 2010) All participants in this study are kept anonymous, and this is communicated to them beforehand as well. As the study does not impose any experimental conditions on the participants but instead observes them during their usual procedure of working in groups, relevant threats to the participants' personal safety have not been identified. Participation in a study should be voluntary, and the research subjects should be sufficiently informed about the study (Denscombe, 2010). Informed consent is obtained from all participants before observing them to fulfill this criterium. A document in which information about the study and how the retrieved information would be managed is signed to put the consent on record. In this document, the participants were also informed that they could withdraw their consent at any time, without any following consequences. To ensure scientific integrity, Denscombe (2010) states that the researchers should be open and explicit about the study and the intentions for collecting data from the participants. In the aforementioned consent form, the interviewees signed they were informed that data would be collected through recordings in video and audio and that it later would be transcribed, as well as who would have access to the data collected. To ensure that the research complies with existing laws, aspects of ownership of the data and how to keep the data private and secure must be considered. This was ensured during the research process by storing the data locally on a personal laptop, not sharing it with third parties, and deleting it after the completion of the thesis. Moreover, no conflict with any prevailing laws has been found.

## Chapter 4

# Results

### 4.1 Observation Protocol

During the data collection process, three separate sessions were recorded over the course of one week. Each session lasted about two hours, which adds up to six hours of observation material overall. An observation protocol was set up before starting the observations. It includes a timestamp, a short description of the observed interaction, and the corresponding category and classification from the behavior coding scheme. The observation protocol was revisited and completed by rewatching the recordings later to ensure it captures all interactions and the categorization and classification are done in a consistent matter.

### 4.2 Work Setting

The student group constellation was made up of three participants in two sessions, whereas one session consisted of four people working on the project. They were sitting in close proximity to each other in a large room with other students also present. The student group's goal was to develop an application that runs on a VR headset. They were designing a digital twin of a houseplant that captures the present status of the plant, including water levels, nutrition of the soil, and light conditions. The digital twin can be used for diagnosing deficiencies in the plant, like brown or yellow leaves, stretching, or irregular spots. The virtual plant can be modified by pruning leaves or adding nutrients and water. Another functionality is the prediction which makes it possible to see the plant in three months time. This projection considers growth according to the nutritional conditions and the pruning. As this application features a virtual object that can be seen in real-world surroundings, it can be characterized as a MR application, more specifically, an AR application. The technology used in this student group work consisted of the personal laptops of the participants and two headsets: the Oculus Quest 2 which is a VR headset that is able to display in-

teractive 3D-videos and comes with touch control handheld and a hand-tracking technology to use one's hand hands for interacting with the virtual environment (Meta, 2023a); and the Oculus Pro which is a MR headset that enables the user to see their physical space via a stereoscopic pass-through functionality while overlaying 3D virtual objects in the space that can be manipulated by hands or the touch pro handheld controllers (Meta, 2023b). By the integration of a pass-through functionality for a video of the physical surroundings, the Oculus Quest 2 can offer a MR experience (Meta, 2023a). The development editor Unity is used for the development of the virtual interactive scenario. Unity is a platform for "creating and operating interactive, real-time 3D (RT3D) content" (Unity, 2023).

Over the course of all three sessions, the team members S1, S2, S3, and S4 exhibited a high degree of individual responsibility, which could be observed in them each working in an autonomous fashion on different tasks on their own laptops. S1 worked on producing a progress report in the form of a presentation that was needed to successfully finish the course. S2, who was only present in the third observation session, worked on producing a visualization of an object needed for the simulation. The other two members, S3 and S4, were tasked with further developing the code for the digital twin application and testing the program's current state with the headsets. Since they were working on the same tasks, the two last-mentioned students had the most interactions with each other.

Another point worth mentioning is the open and friendly working atmosphere that was prevalent throughout the student group work. It was clearly visible that the group had an amicable and constructive way of communicating with each other. When someone asked for help or clarification, the others were quick to respond and share their views and knowledge. In many situations, students from different working groups (S5, S6 and S7) were also involved, and advice and guidance were both sought and given without any noticeable gatekeeping of information. An example of how this interaction looks can be found below (see table 4.1). Here, a student from another group (S5) explains the settings of the Oculus headset to the student S4 and later confirms that the offered advice was helpful.

Timestamp	Description	Category	Classification
14:40	S4 to ask S5 for help on the camera settings on the Oculus.	Communication	Collaboration request
14:48	S5 explains the settings	Communication	Advice
18:48	S5 checks up on the solution	Communication	Status

Table 4.1: Observation Protocol Excerpt - S5 involvement

### 4.3 Data Analysis

The codes directly connected to the use of immersive technology can be found under the category "Headset Use" as the different classifications "Single use", "Shared use in same lobby", and "Hand over".

In the **single use interaction**, one student puts on a headset and can see the simulation. Two main reoccurring behavioral patterns were found whenever a single user took up a headset. The first one of them was that shortly after equipping the headset, the student wearing the headset made configurations on the headset or on their laptop in Unity before taking it off again. This pattern is visualized in figure 4.1, where the two identified and coded events are shown as rectangles, and the arrows represent the sequential flow of events. The classifica-

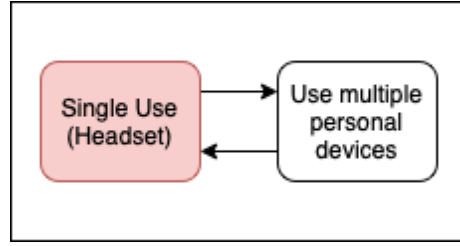


Figure 4.1: Behavioral Pattern during Single use of Headset with no increased Communication

tion "Single Use (Headset)" signifies that one student picked up the headset and started the MR application. The following event is classified as "Use multiple personal devices" and corresponds to the same student making configurations on their laptop. The diagram is the result of the sequential analysis done on the obtained data from the observation protocol (see table 4.2).

Timestamp	Description	Category	Classification
26:11	S4 puts on headset	Headset	Single use
26:30	Headset off, S4 makes configuration on the computer	Collaboration Configuration	Use multiple personal devices

Table 4.2: Observation Protocol Excerpt - Headset Single Use with no increased Communication

The second behavioral pattern is characterized by a sharp increase in communication between students S3 and S4, who are working on developing the AR application directly after the headset is put on by one of them. An example of such an observed pattern is shown in figure 4.2. In the diagram it can be seen, that six events have been recorded in connection to the "Single Use (Headset)" classification. S3 wears the headset and S4 provides guidance within the virtual space which is depicted by the "Advice/ Instruction" classification. S3 continues to seek orientation in the MR application, represented by the "Orientation/ Understand" classification. The "Information" classification follows where S3 communicates what they are doing or seeing. Following in sequence is the "Use multiple personal devices" event which translates to the student S3 using their laptop to work on the configuration in Unity. Another sequence of "Single use (Headset)" starts after this, is followed by an "Information" event and ends in "Agreement" because S3 and S4 decide with the given information on what

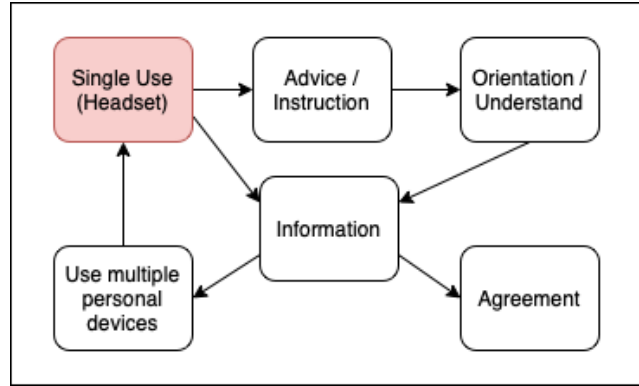


Figure 4.2: Behavioral Pattern during Single use of Headset with increased Communication

Timestamp	Description	Category	Classification
1:27:46	S3 wears glasses	Headset	Single use
1:28:39	S4 guides S3 towards the red room	Communication	Instruction
1:28:44	S4 "What should we do here?"	Communication	Orientation
1:29:08	S3 "I am trying to see the object here, but it is not working"	Communication	Information
1:29:42	S3 headset off to configure something on his own screen in Unity	Collaboration Configuration	Use multiple personal devices
1:30:15	S3 headset back on	Headset	Single use
1:30:25	S3 found some fix: go to development dashboard, add test users	Communication	Information
1:32:05	S3 and S4 agree that they need to add test users	Communication	Agreement

Table 4.3: Observation Protocol Excerpt - Headset Single use with increased Communication

action should follow. The corresponding observation protocol excerpt of this situation can be found in table 4.3.

The classification "Shared use in same lobby" under the category "Headset" was first observed in the second observation session. **Shared use in the same lobby** signifies that the two students working on the production of the MR application enable an option to join the same virtual lobby in the Oculus App via signing up with their accounts. Through this, they can enter the same view of the application and share the MR space. A snapshot of the students using the headsets with the shared use in the same lobby can be found in figure 4.3. A behavioral pattern that represents an interaction between S3 and S4 where they apply the shared use in the same lobby can be seen in figure 4.4, and the corresponding observation protocol is seen in table 4.4. In the behavioral pattern, the multitude of elements is perceivable at first glance. The situation started with a "Status" event, signifying that S3 asks about the status of the "Shared use in the same lobby"- work mode of the headsets. The following



Figure 4.3: Students Working in a Shared Lobby

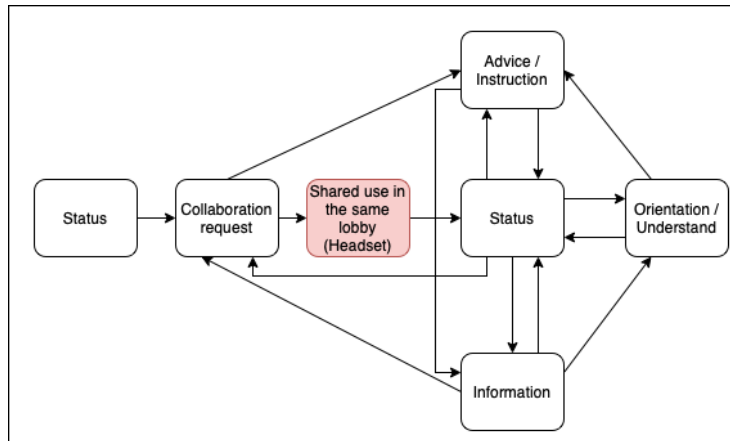


Figure 4.4: Behavioral Pattern during Shared use in Same Lobby of Headset

event is classified as "Collaboration request" because the student S4 invites S3 to try out the headset mode together. Then follows the "Shared use in same lobby" event where both students put on and use the headset. What follows this is a series of "Communication" events, namely the "Status" event where the students exchange what they are seeing in the virtual space and what they are planning on doing next, the "Information" event where one is providing the other with bits of information, the "Advice/ Instruction" event where one student provides guidance to the other or directs them towards an action, and the "Orientation/ Understand" event in which the students seek orientation in the situation.

Timestamp	Description	Category	Classification
7:44	S3 to S4 "is it working with the two headsets?"	Communication	Status
7:46	S4 "yes, would you like to try?"	Communication	Collaboration request
7:47	S4 is trying out the headset, they connect to the same application (with S3)	Headset	Shared use in same lobby
8:20	S4 "I'll just exit the app and then reconnect again"	Communication	Status
9:10	S4 "you can see, right?"	Communication	Status
9:30	S3 "it's very hard for me to read the text"	Communication	Information
9:19	they check which options to select	Communication	Orientation
10:30	S4 "you need to create the anchor and place it at your eye level"	Communication	Instruction
10:34	S3 "you need to see the green one as a 2D dimension"	Communication	Information
11:00	(S4 creates a cube) "can you see the cube?"	Communication	Status
11:05	S3 "yes I can"	Communication	Information
11:06	S3 "how do I create a cube myself?"	Communication	Collaboration request
11:10	S4 explains how to place a cube	Communication	Advice
11:45	S4 "can you see the anchor I placed?"	Communication	Status
11:50	S3 "I put too many anchors, how do I remove them? What are they for"	Communication	Collaboration request
11:55	S5 explains that anchors are for configuration and you should only place one	Communication	Advice
12:20	they exit the program, now S4 should do the calibration	Communication	Instruction

Table 4.4: Observation Protocol Excerpt - Headset Shared use in same Lobby



The third category of use within the headset classification is called "Hand over". Only two instances of this interaction were observed over the course of all sessions. Whenever a **handover** of the headset occurred, a student previously wearing the headset passed the headset to another student with the words "Would you like to try?" or "Here, now you can see it yourself". One instance of the handover can be found in table 4.5 and is converted to a behavioral pattern (see figure 4.5). The behavioral pattern reflects a common pattern for single use

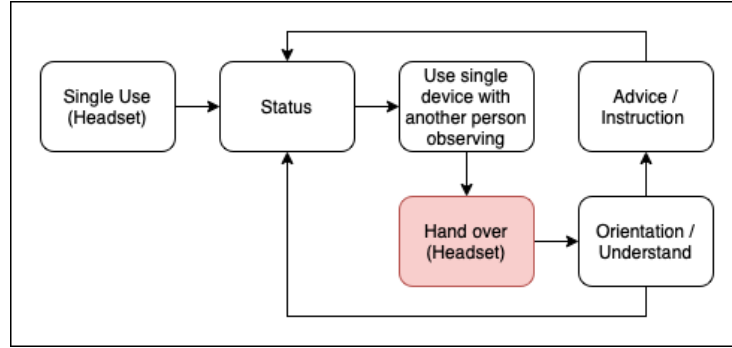


Figure 4.5: Behavioral Pattern during Hand over of Headset

interaction with the headset before the handover happens: In the "Single Use (Headset)" event preceding the handover, S3 shares the status that the hand behavior in the application seems to be faulty ("Status" event). S3 then tries to fix the bug on his own personal device, with S4 watching the screen and following the configuration steps that S3 is performing ("Use single device with another person observing" event). Afterwards, the "Hand over (Headset)" from S3 to S4 takes place so that S4 can test out whether the bug prevails or was fixed. During wearing the headset, the "Communication" categories "Orientation" and "Advice" occur, signifying that S4 is looking for help in understanding the headset's functionalities, and S3 tries to provide guidance. After taking off the headset, the situation is assessed via exchanging another "Status" between S3 and S4 and then going into an "Orientation/ Understand" phase in which S4 wonders about what could be changed in the code to overcome the current problems in the application.

Timestamp	Description	Category	Classification
2:29:10	S3 tries on headset	Headset	Single use
2:29:32	S3 “Something does not work, the hand should behave differently in the simulation”	Communication	Status
2:30:15	S4 and S3 collaborate to change the hand behavior settings	Collaboration Configuration	Use single device with another person observing
2:30:54	S3 Would you like to try?“ (with the headset)	Headset	Hand over
3:32:10	S4 wonders if it is possible to place the anchor with just hand tracking	Communication	Orientation
3:32:16	S3 answers no, S4 picks up the hand controllers	Communication	Advice
3:33:40	S4 takes off headset it doesn’t work“	Communication	Status
3:33:50	S4 What can we change?“	Communication	Orientation

Table 4.5: Observation Protocol Excerpt - Headset Hand over

## Chapter 5

# Discussion

### 5.1 Priority of Shared Situation Awareness

This study found that in student group work with immersive technology, shared SA is only sparsely prioritized. Over the course of all observed sessions, the group exhibited a remarkably high level of individual work with only occasional efforts to form shared SA. This can be deduced when looking at how long the different group members work on their personal devices without looking at each other, the other students' devices, or communicating with each other. A snapshot of a typical group work situation with everyone working individually is seen in figure 5.1. It is clearly visible that the task of developing an application for immersive technology is approached by breaking up the total workload into individual subtasks and dividing those tasks among the group members according to their knowledge and talents. Every student is therefore very involved with their own work and only occasionally would inform themselves about the others' work status by directly enquiring about this information. In summary, it can be said that the group valued division of labor with high individual SA over close collaboration with high shared SA. This is very similar to what Kulyk et al. (2008) conclude for the importance of group awareness in their researched application field of scientific research. As both situations are not highly critical in terms of time constraints and dangerous consequences, it is not necessary to constantly maintain a very high level of shared situational awareness. In other situations, such as aircraft operation, where the concept of SA emerged, maintaining a high awareness is crucial to avoid harsh consequences that could be even life-threatening (Endsley, 1995). The individualistic work approach can be explained when looking at the complexity of the task of developing an application for a virtual reality headset in an educational context: The application needs to be developed and coded in an editor, digital objects need to be designed for the visuals in the application, the headset must be tested for correct function, a presentation needs to be prepared to fulfill a course requirement, and many more small subtasks. All of the tasks require different toolsets, knowl-

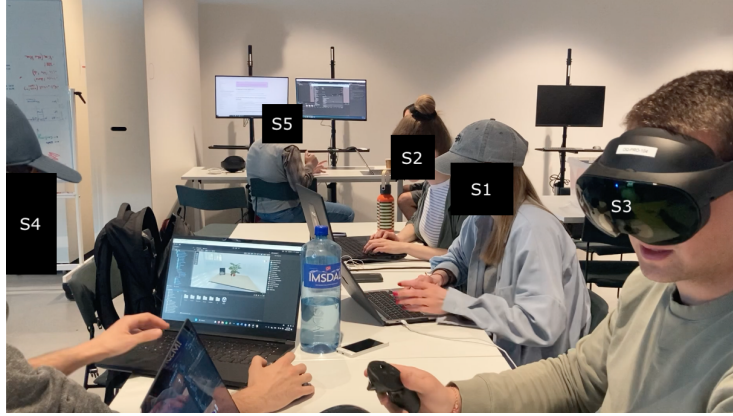


Figure 5.1: Students Working Individually

edge, and skills and it seems logical to divide them up according to the team members' prior experience. As Bolstad et al. (2005) state, personnel selection and assignment to tasks affect what individual factors will contribute to the SA, and thus the team performance and team outcomes.

## 5.2 Communication

Another result of the observations is that communication, and more specifically what was coded as the "status" interaction, is used to build shared SA. The "status" classification, which signifies that a student asks another student about their current objective and progress, serves as an interesting indication of two things when looking at the importance of shared SA: Firstly, it shows that the students lose touch with what the other person does at some point. The shared SA can thus not be kept over a longer period of time or is not prioritized when the students are not working collaboratively on a common task. Secondly, the status interaction shows an active effort to increase the SA. By using the "status" interaction, the student reconnects with the team members through regular check-ups. The fact that this technique is used repeatedly shows that understanding their group members' work goals and status has high importance for all although they do not follow every step of the execution of tasks closely. The status interaction is used in multiple situations regardless of whether immersive technology is used or not. It can therefore be called a general strategy to form shared SA and is not limited only to the use of immersive technology. The literature supports this finding as communication is named one of the main team factors that contribute to forming shared SA in the study of Bolstad et al. (2005). They highlighted the importance of supporting communication and collaboration through techniques and tools to foster high group awareness in

teams. Although it might seem simple, the frequent tuning in with each other through the status interaction can be considered one of the communication techniques that Bolstad et al. (2005) was referring to. Especially when the tasks are not carried out by all team members together but rather divided across them, communication becomes even more important as the flow of information about the work progress does not come naturally because not everyone participates in the same activity. The same conclusion is drawn by Laurila-Pant et al. (2023) and Fysarakis et al. (2022) who highlight the importance of information sharing across different organisations to form shared SA.

### 5.3 Use of Immersive Technology

There are several interesting findings regarding the topic of shared SA when using immersive technology. The four different behavioral patterns that were discovered during the different modes of use of the headset, namely the "Single use", the "Shared use in the same lobby", and the "Hand over" show different levels of shared SA. In the first pattern of the "Single use" (see figure 4.1), there is no communication between the team members, and it can therefore be assessed that the group awareness is limited to what the other team members can observe in the physical space. Occasionally, other students glance up from their screens to look at the student wearing a headset which shows that they perceive what is happening around them and what tasks the others are working on. However, there is no way for the other students to know what the person wearing the headset is seeing in the virtual space. That makes it impossible to assess whether the headset and the AR application behave in a desired way. The second behavioral pattern that occurs during the "Single use" of the headset, is characterized by a sharp increase in communication (see figure 4.2). The other student would shift their attention from their laptop screen to the headset-wearing person. They communicate by using phrases like "tell me when you see the block I placed in the room" followed by "I cannot see the block", or navigating the headset-wearing student by "go towards the blocks on your right", and asking for the current intention by asking "what are you trying to do?". The communication classifications "Information", "Status", and "Instruction/Advice" are predominantly found in the interaction between the two students when one of them wears the headset. It shows that by exchanging information about what the headset-wearing person is seeing, all involved students are working towards a common understanding of the situation, thus trying to form a shared SA. Additionally, by giving advice and guidance for the use of the application, the students can align their short- and long-term goals and develop a similar strategy for achieving them. This heightens group awareness as well. In the working mode "Shared use in same lobby" with the headset, it could be observed that S3 and S4 communicated throughout wearing the headsets (see figure 4.4). A typical interaction that has been observed involves asking if the other student can see something virtual in the MR environment

(“Can you see the anchor I placed?”) and the other student responding by talking about what the person is seeing (“I cannot see you in the virtual space”). This corresponds to the classifications “Status” and “Information” of the coding scheme. Status is used whenever two or more people check up on each other about their current views, state of work, or opinions. It shows that they try to understand the current work environment of their peers and increase shared SA by doing this. Furthermore, “Collaboration Request” and “Advice/Instruction” are widely used. This signifies that someone asks for help or guidance with the technology, and another person offers this advice which showcases a high level of cooperation and working towards a common understanding. Moreover, it can be seen that through giving instructions, one person takes over the leading role while using the VR equipment which makes working towards a unified goal much easier. As having a purpose to direct the activities is a significant part of SA, this can be seen as another way of the group to increase their shared SA. The student group had worked towards enabling the shared use in the same lobby since the first observed session. They recognized the affordances of this working mode early on, the possibility of seeing the same image through the headset and being able to interact with objects in the same mixed-reality space facilitates communication greatly. The last observed behavioral pattern can be found in connection to the “Hand over” of the headset (see figure 4.5). Similar to other instances of the use of immersive technology with increased communication, a high degree of exchange of information and guidance is exhibited, which points towards a formation of shared SA. The act of handing over the headset itself shows that a student wants another person to see the same image in the mixed-reality environment that they were seeing before. Thus, the student strives to create a common understanding of the prevalent situation and get the other student on board with their problem-solving process.

In summary, the most important finding regarding the use of immersive technology is that the students had a preferred mode of working with the VR headset, which was the “Shared use in the same lobby” mode. Much energy was put into enabling the correct functioning of this mode of use, and group communication increased greatly when using it. The “shared use in the same lobby” mode on the VR headset is a good example of what Bolstad et al. (2005) mean when they propose technology that supports collaborative tasks via offering a shared medium for all team members to be in the same environment. By seeing the same virtual space through the headset, the students are able to communicate about potential bugs or anomalies that they both see in the simulation. To improve the work situation for the team members even more, two additional functions for collaborative technology have been put forward by Kulyk et al. (2008). The first one is a highlighting function which allows one team member to direct the others’ attention towards one specific detail or object on a shared device. This would be a helpful modification for the shared use in the same lobby mode on the VR headset as it was often observed that the students were having trouble understanding what object a team member was referring to. A highlighting function could remedy this. The second feature proposed is storing and visualizing the changes made by the group members to support their un-

derstanding of the situation (Kulyk et al., 2008). In this use case, introducing this kind of visualization is not deemed particularly useful since the students are not changing elements in the virtual environment of the immersive technology per se. Changes are being made in the programming editor, and the students are recognizing them via communication or looking at the computer screen of the person editing the code.

## **5.4 Ethical and societal consequences**

As already discussed in the methods chapter (see section 3.5), all precautions were taken to ensure that the study can be conducted in an ethical manner. No harmful consequences are expected for the participants of the observation, and the recorded data will stay confidential. As for the societal consequences of this research, this research highlights the importance of designing immersive technology in a way that encourages and supports collaboration. Immersive technology holds great affordances for making teamwork more engaging, but to reap the benefits, the technology must help increase shared SA rather than obstruct it.

## Chapter 6

# Conclusion

This study set out to research how shared SA is formed in student groups that work with immersive technology. To this end, an observation of different working sessions of a student group was carried out, and the obtained material was analyzed using sequential analysis. It was found that the students do not prioritize shared SA, but they instead work in a very individual way where they divide smaller subtasks among themselves and focus on their own tasks first and foremost. Whenever they want to inform themselves about the work status of another student, they openly and directly ask the other person which helps build shared SA. When using immersive technology, communication also plays a crucial role in building shared SA. The students would speak about what they are seeing in the virtual environment, communicate their goals, and ask and give advice to each other. It was also observed that the students seek to use the immersive technology in a way that allows more than one person to see the same virtual environment. They implement this by handing over the VR headset or working in a mode where they can use two headsets and connect them to the same lobby so that they can enter the same virtual space and see the same elements at the same time.

### 6.1 Limitations

As the study was carried out in the context of a master's thesis, the time for carrying out the actual observation was very limited. In spite of the researcher's assessment that the obtained data contains enough diverse interactions to provide a full picture of the shared SA, it is possible that the observation time of six hours is, in fact, not enough to disclose all aspects. With longer observation time, the interaction during the mode of use of "shared use in the same lobby" could have been studied in more detail as the student group figured out how to use the virtual headset in this way rather late. Another limitation of the study is that there is arguably a potential for bias that is introduced by the subjectivity of the researcher. As the researcher worked alone on the observation and did



both - the development of the coding scheme and the recording of the events, an observer agreement, as it is discussed in Bakeman and Gottman (1997), cannot be guaranteed. This lowers the reliability of the method to a certain extent, because if the data analysis were to be reiterated, there is a chance for different outcomes due to a different coding of the observed events. The design of the behavior coding scheme itself could also be revisited. In the process of transforming the behavior code from Biehl et al. (2007) to fit this study's condition, the categories and classifications were altered. This lowers the validity of the research method since the behavior coding scheme is not used in other literature and it is therefore not guaranteed that it captures every aspect of what is intended to be analyzed. However, this adaptation is deemed necessary to reflect the observation correctly. The generalizability of this study should be assessed carefully as well since a case study investigates one particular instance, in this case a student group, in great detail and conclusions are drawn from the specific observation. To a certain extent, the findings of the study can be considered generalizable as they are documented in related research as well. However, not all conclusions must be true for similar cases of group work, especially if the conditions, like the education context, change.

## 6.2 Future research

This study has made the first steps in analyzing students' SA in a collaborative setting with the use of immersive technology. To contribute further to the knowledge base around this topic, further research could extend the research subjects to different groups of people. It could be interesting to study the impact of immersive technology on collaboration between students from other study backgrounds than technology, younger pupils, or working professionals that use immersive technology in their job life. Furthermore, the method of using observation could be exchanged for another method, like an experiment, to obtain more objective results. By conducting an experiment, quantifiable measures of shared SA can be collected. This should make it possible to assess and compare the effect of immersive technology on the SA of a group. This study endorses the development of the features proposed by Kulyk et al. (2008) to foster effective collaboration via technology. A study to assess their impact would help improve immersive technology in terms of group work support.

# Bibliography

- Al-Moteri, M., Alfuraydi, A. A., Alsawat, A. Z., Almulhis, R. S., Alnadwi, B. S., Youssef, H. A. M., & Althobiti, E. S. (2022). Shared situational awareness within the hospital emergency context: A scoping review. *Healthcare*, 10(8). <https://doi.org/10.3390/healthcare10081542>
- Bakeman, R., & Gottman, J. M. (1997). *Observing interaction: An introduction to sequential analysis*. Cambridge university press.
- Berkman, M. I., & Akan, E. (2019). Presence and Immersion in Virtual Reality. *Encyclopedia of Computer Graphics and Games*, 1–10. [https://doi.org/10.1007/978-3-319-08234-9\\_162-1](https://doi.org/10.1007/978-3-319-08234-9_162-1)
- Biehl, J. T., Czerwinski, M., Smith, G., & Robertson, G. G. (2007). FASTDash: A visual dashboard for fostering awareness in software teams. *Conference on Human Factors in Computing Systems - Proceedings*, 1313–1322. <https://doi.org/10.1145/1240624.1240823>
- Bolstad, C. A., Cuevas, H. M., Gonzales, C., & Schneider, M. (2005). Modeling Shared Situation Awareness.
- Brondi, R., Alem, L., Avveduto, G., Faita, C., Carrozzino, M., Tecchia, F., & Bergamasco, M. (2015). Evaluating the impact of highly immersive technologies and natural interaction on player engagement and flow experience in games. In K. Chorianopoulos, M. Divitini, J. Baalsrud Hauge, L. Jaccheri, & R. Malaka (Eds.), *Entertainment computing - iccc 2015* (pp. 169–181). Springer International Publishing.
- Bunker, D. (2020). Who do you trust? the digital destruction of shared situational awareness and the covid-19 infodemic [Impact of COVID-19 Pandemic on Information Management Research and Practice: Editorial Perspectives]. *International Journal of Information Management*, 55, 102201. <https://doi.org/https://doi.org/10.1016/j.ijinfomgt.2020.102201>
- Burke, A. (2011). Group Work : How to Use Groups Effectively. *Journal of Effective Teaching*, 11(2), 87–95.
- Chang, H. Y., Hsu, Y. S., & Wu, H. K. (2016). A comparison study of augmented reality versus interactive simulation technology to support student learning of a socio-scientific issue. *Interactive Learning Environments*, 24(6), 1148–1161. <https://doi.org/10.1080/10494820.2014.961486>

- Chang, K.-E., Chang, C.-T., Hou, H.-T., Sung, Y.-T., Chao, H.-L., & Lee, C.-M. (2014). Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum. *Computers Education*, 71, 185–197. <https://doi.org/https://doi.org/10.1016/j.compedu.2013.09.022>
- Chen, C.-h., & Hwang, G.-j. (2017). Effects of the team competition-based ubiquitous gaming approach on students' interactive patterns, collective efficacy and awareness of collaboration and communication. *Educational Technology and Society*, 20(May 2019), 87–98.
- de Belen, R. A. J., Nguyen, H., Filonik, D., Del Favero, D., & Bednarz, T. (2019). A systematic review of the current state of collaborative mixed reality technologies: 2013–2018. *AIMS Electronics and Electrical Engineering*, 3(2), 181–223. <https://doi.org/10.3934/ElectrEng.2019.2.181>
- Denscombe, M. (2010). *The Good Research Guide for small-scale social research projects* (Fourth Edition).
- Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Situational Awareness*, 37(1), 9–41. <https://doi.org/10.4324/9781315092898-13>
- Endsley, M. R. (2012). Situation Awareness. In *Handbook of human factors and ergonomics, fourth edition* (pp. 553–568). John Wiley & Sons, Inc.
- Endsley, M. R. (2020). The Divergence of Objective and Subjective Situation Awareness: A Meta-Analysis. *Journal of Cognitive Engineering and Decision Making*, 14(1), 34–53. <https://doi.org/10.1177/1555343419874248>
- Fearon, C., McLaughlin, H., & Eng, T. Y. (2012). Using student group work in higher education to emulate professional communities of practice. *Education and Training*, 54(2-3), 114–125. <https://doi.org/10.1108/00400911211210233>
- Fysarakis, K., Mavroeidis, V., Athanatos, M., Spanoudakis, G., & Ioannidis, S. (2022). A blueprint for collaborative cybersecurity operations centres with capacity for shared situational awareness, coordinated response, and joint preparedness. *2022 IEEE International Conference on Big Data (Big Data)*, 2601–2609. <https://doi.org/10.1109/BigData55660.2022.10020736>
- Kulyk, O., Van Der Veer, G., & Van Dijk, B. (2008). Situational awareness support to enhance teamwork in collaborative environments. *ACM International Conference Proceeding Series*, 369. <https://doi.org/10.1145/1473018.1473025>
- Laurila-Pant, M., Pihlajamäki, M., Lanki, A., & Lehtikainen, A. (2023). A protocol for analysing the role of shared situational awareness and decision-making in cooperative disaster simulations. *International Journal of Disaster Risk Reduction*, 86, 103544. <https://doi.org/https://doi.org/10.1016/j.ijdr.2023.103544>
- Meta. (2023a). <https://www.meta.com/se/en/quest/products/quest-2/>
- Meta. (2023b). This is meta quest pro [Accessed:21-05-2023]. <https://www.meta.com/se/en/quest/quest-pro/#overview>

- Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, 77(12), 1321–1329.
- Narri, V., Alanwar, A., Mårtensson, J., Norén, C., Dal Col, L., & Johansson, K. H. (2021). Set-membership estimation in shared situational awareness for automated vehicles in occluded scenarios. *2021 IEEE Intelligent Vehicles Symposium (IV)*, 385–392. <https://doi.org/10.1109/IV48863.2021.9575828>
- Nguyen, H., Marendy, P., & Engelke, U. (2016). Collaborative Framework Design for Immersive Analytics. *2016 Big Data Visual Analytics, BDVA 2016*. <https://doi.org/10.1109/BDVA.2016.7787044>
- Salimian, M. H. (2015). Exploring group awareness in a mixed reality collaborative environment. *UbiComp and ISWC 2015 - Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and the Proceedings of the 2015 ACM International Symposium on Wearable Computers*, 495–502. <https://doi.org/10.1145/2800835.2801654>
- Salmon, P. M., Stanton, N. A., Walker, G. H., Jenkins, D., Ladva, D., Rafferty, L., & Young, M. (2009). Measuring Situation Awareness in complex systems: Comparison of measures study. *International Journal of Industrial Ergonomics*, 39(3), 490–500. <https://doi.org/10.1016/j.ergon.2008.10.010>
- Schei, G. S., & Giske, R. (2020). Shared situational awareness in a professional soccer team: An explorative analysis of post-performance interviews. *International Journal of Environmental Research and Public Health*, 17(24). <https://doi.org/10.3390/ijerph17249203>
- Soliman, M., Peetz, J., & Davydenko, M. (2017). The impact of immersive technology on nature relatedness and pro-environmental behavior. *Journal of Media Psychology*, 29(1), 8–17. <https://doi.org/10.1027/1864-1105/a000213>
- Sonawani, S., & Amor, H. (2022). When and where are you going? a mixed-reality framework for human robot collaboration. *5th International Workshop on Virtual, Augmented, and Mixed Reality for HRI*. [https://openreview.net/forum?id=BSrx\\_Q2-Akq](https://openreview.net/forum?id=BSrx_Q2-Akq)
- Suh, A., & Prophet, J. (2018). The state of immersive technology research: A literature analysis. *Computers in Human Behavior*, 86, 77–90. <https://doi.org/10.1016/j.chb.2018.04.019>
- Tabrez, A., Luebbers, M. B., & Hayes, B. (2022). Descriptive and prescriptive visual guidance to improve shared situational awareness in human-robot teaming. *Proceedings of the 21st International Conference on Autonomous Agents and Multiagent Systems*, 1256–1264.
- Unity. (2023). Get started with unity [Accessed:21-05-2023]. <https://unity.com/learn/get-started>
- Yiu, C. Y., Ng, K. K., Li, X., Zhang, X., Li, Q., Lam, H. S., & Chong, M. H. (2022). Towards safe and collaborative aerodrome operations: Assessing shared situational awareness for adverse weather detection with eeg-

enabled bayesian neural networks. *Advanced Engineering Informatics*, 53, 101698. <https://doi.org/https://doi.org/10.1016/j.aei.2022.101698>

## Appendix A

# Informed Consent Form

**Informed Consent Form**  
**Situational Awareness in Student Group Work When Using Immersive Technology**

Dear study participant,

Thank you for agreeing to take part in my research study. The study aims to find out how the usage of immersive technology influences the groups' behavior in a collaborative task. In order to investigate this, an observational approach has been chosen. A student group work session will be recorded (including video and audio). The material will then be analyzed using a behavior code scheme.

No specific preparation is needed from your part – the group work should be conducted with no concern for the recording.

- I..... voluntarily agree to participate in this research study.
- I have had the purpose and nature of the study explained to me in writing and I have had the opportunity to ask questions about the study.
- I understand that participation involves being recorded in video and audio during my group work.
- I agree to my group work being recorded.
- I understand that all information I provide for this study will be treated confidentially.
- I understand that I may be quoted while staying anonymous in the master thesis written in Stockholm university.
- I understand that in any report on the results of this research my identity will remain anonymous. Due to the analysis of the recording (meaning the coding of the group behavior) that will be done afterwards, no identity will be revealed.
- I understand that I am free to contact any of the people involved in the research to seek further clarification and information.
- I understand that even if I agree to participate now, I can withdraw at any time.

*Tabea Bröring, tabr4518@student.su.se*

Signature of participant, Date

Signature of researcher, Date

I believe the participant is giving informed consent

-----

-----