Technical University of Munich

School of Computation, Information and Technology

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Master's Thesis in Robotics, Cognition, Intelligence

Spatial Computing in Human-Computer Interaction: Designing a Mixed Reality HMD Experience around Process Mining for Celonis Prospects

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Spatial Computing in der Mensch-Computer Interaktion: Gestaltung eines Mixed-Reality HMD-Erlebnisses rund um Process Mining für Celonis-Interessenten

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I confirm that this Master's thesis is my own work and I have documented all sources and material used.

Munich, 15th March 2024 Michael Philipp Sodamin

Abstract

Recent advancements in Mixed Reality (MR) technology, particularly in business applications, have sparked renewed interest in experimenting with MR among corporate leaders. This research aims to develop an MR experience designed for the Celonis Executive Briefing Center (EBC). The goal is to educate business leaders about Celonis and its most recent innovative technology, Object-Centric Process Mining (OCPM). OCPM is a technical data-platform change. Explaining the resulting business advantages effectively and interestingly poses a unique challenge. The study introduces a narrative that highlights and interactively illustrates the key benefits of OCPM with real-world analogies and representations. The experience was built using Unity and deployed on the Meta Quest 3 following a user-centric approach, featuring video passthrough, hand-tracking, and room scans. It is intended to create excitement, foster a deeper understanding of the topic, and improve the overall EBC visit. The prototype is tested through a formative study targeting potential Celonis buyers, the company's employees, and partners. The results show that the experience should be included in sales interactions. It complements the current EBC offering by creating exciting and memorable situations that might improve the EBC's effectiveness. While the implementation is perceived as educational, it should not be used as a standalone learning experience but accompanied by educational sessions and informational material. Due to its positive perception, Celonis decided to roll out the installation and evaluate further areas of use.

Zusammenfassung

Jüngste Fortschritte in der Mixed-Reality-Technologie (MR), insbesondere in geschäftlichen Anwendungen, haben bei UnternehmensführerInnen erneutes Interesse geweckt, mit MR zu experimentieren. Diese Studie zielt darauf ab, ein MR-Erlebnis zu entwickeln, das für das Celonis Executive Briefing Center (EBC) konzipiert ist. Das Ziel ist, GeschäftsführerInnen über Celonis und dessen neueste innovative Technologie, das objektzentrierte Prozessmining (OCPM), aufzuklären. OCPM ist ein technische Änderung an der Grundlage der Daten-Plattform. Die resultierenden Geschäftsvorteile effectiv und interessant zu erklären stellt eine besondere Herausforderung dar. Der erstelle Prototype erzählt ein Narrativ, werlcher die wichtigsten Vorteile von OCPM durch Analogien und greifbaren Darstellungen hervorhebt und interaktiv veranschaulicht. Das Erlebnis wurde auf Unity mit einem Benutzerzentrierter Designansatz entwickelt und auf der Meta Quest 3 bereitgestellt, mit Funktionen wie Video-Durchsicht, Hand-Tracking und Raumscans. Es soll Begeisterung wecken, ein tieferes Verständnis des Themas fördern und den gesamten EBC-Besuch verbessern. Der Prototyp wurde durch eine formative Studie mit Celonis-Interessenten, MitarbeiterInnen des Unternehmens und PartnerInnen getestet. Die Ergebnisse zeigen, dass das Erlebnis in Verkaufsinteraktionen einbezogen werden sollte. Es ergänzt das aktuelle EBC-Angebot, indem es aufregende und einprägsame Situationen schafft, die die Wirksamkeit des EBCs verbessern könnten. Obwohl die Implementierung als lehrreich wahrgenommen wird, sollte sie nicht als eigenständige Lernerfahrung genutzt werden, sondern von weiteren informativen Agendapunkten und Informationsmaterial begleitet sein. Aufgrund der positiven Wahrnehmung entschied sich Celonis, die Installation zeitnah auszurollen und weitere Einsatzbereiche zu evaluieren.

Contents

1 Introduction

1.1 Motivation

Celonis is the market leader in process mining, according to Everest [1] and Gartner [2]. Its software helps its customers "model, analyze, and optimize [their] business processes." [3] The company is usually among the first to drive innovation by implementing novel business process mining techniques. When the Celonis software is sold, the deal size of acquiring a software license is usually 6-7 digits per year [4], making every interaction with a potential customer very valuable. Celonis must convince customer prospects of the value their software can provide by compellingly creating excitement about the product and explaining underlying technologies.

One of these new technologies recently implemented in Celonis' software is Object Centric Process Mining (OCPM), with which the company has introduced a new way of processing and displaying business process data more effectively. OCPM is becoming the new foundation of the Celonis software and is essential in upcoming sales. Compared to the traditional Case Centric Process Mining (CCPM), OCPM adds the dimension of *object type* to every recorded activity. Therefore, it is referred to as "Process Mining in 3D" by its inventor, Prof. van der Aalst [5].

Lately, Mixed Reality (MR) has seen a new rise in importance, with the estimated market size almost tripling from 2021 to 2024 [6]. Also, the excitement around the Apple Vision Pro entering the market increased awareness among professionals [7]. Spatial computing promises a new way of working with data and computers, which might become more natural and powerful than ever. MR for Celonis could have been researched for multiple use cases; from data visualization to improving operational tasks. During the initial discussions with Celonis decision-makers about potential thesis topics, it was agreed that the first project should have a direct, measurable impact on the company. Consequently, we steered the focus toward enhancing sales interactions to educate about OCPM. Mixed Reality experiences bring many advantages to learning [8] and are commonly used for sales interactions [9], [10].

Single events in a customer's relationship with a product provider, like Celonis, can become "transformational relationship events" when they are especially positive or negative. These events then have a disproportional strong impact on the relationship [11]. Celonis Executive Briefing Centers (EBCs) try to create those positive, transformational events by inviting senior-level decision-makers to the Celonis headquarters in Munich. EBCs accelerate the sales cycle, ensuring customers receive an outstanding and differentiated experience by providing customized presentations, workshops, and discussion rounds with

senior-level Celonis employees. Even though the EBCs are currently successful, they lack innovative experiences different from presentations or discussions.

1.2 Goal

This thesis project aims to research, create, and evaluate a Mixed Reality experience used as an installation in the Celonis Executive Briefing Center, which creates excitement and helps understand Object Centric Process Mining. The goal is to evaluate a mature prototype to understand whether such an MR experience should be used within EBCs. Furthermore, a formative study should assess issues of the prototype and whether Celonis stakeholders support the development into a final installation and how it should be used in the future.

1.3 Scope and Limitations

A Unity prototype on the Quest 3 is researched, designed, and created within four months. It should be mature enough to be shown to Celonis' prospects and communicate the main business advantages of OCPM. The prototype must be suitable for the diverse group of EBC participants, easy to understand, and quick to conduct and prepare. The idea is to create a basic prototype, evaluate it, and potentially add funding afterward to finalize the quality. It should not comprise a detailed technical or academic explanation of OCPM, nor be a standalone experience used without supervision or accompanying program. The prototype must not be high-fidelity or visually complex. The main targeted use-case and application space is the EBC Customer Space in the Munich Celonis headquarters. Other locations must not be taken into consideration.

1.4 Outline

In the following, Chapter 2 *Background* will explain traditional and Object Centric Process Mining to help the reader understand the differences and business importance. Furthermore, a short introduction to learning and sales experiences with Mixed Reality is given. In Chapter 3, the *Methodology* describes the iterative development process, evaluation, and stakeholder management on a high level. After this, the two main setups for qualitative and quantitative *Evaluation* are explained in Chapter 5, and the positive results for excitement creation and neutral results for learning are shown. Implications and next steps are discussed in Chapter 6 for the EBC and Celonis in general. In the end, Chapter 7 concludes that the experience should quickly be brought to usage.

2 Background

The following chapter provides a baseline of understanding for Process Mining and OCPM. It should illustrate the complexity and abstraction needed to understand their business advantages. Additionally, Mixed Reality and its use in education and business is described.

2.1 Process Mining

Process mining is a methodology used in data science to analyze, represent, and improve business processes. It involves creating *event logs* (i.e., records of specific activities and when they happen within a process) to discover, monitor, and enhance real processes by extracting knowledge from them. [12]

As a business topic Process Mining has dramatically increased in importance, growing pre-covid by 140-160% from 2018 to 2019 according to Everest Group [13] and reaching 900 m$ market revenue in 2022 according to Vantage [14].

Within research, the topic is mainly shaped by a single Dutch Professor, Wil van der Aalst, commonly described as the "Godfather of Process Mining" [15]. It is to be noted that he authored most papers and publications in the field and those used in this section. There is currently a lack of broad academic discourse.

The following section explores the basic idea of process mining, the shortcomings of traditional (case-centric) process mining, and how Object-Centric Process Mining can help overcome them. It aims to create a foundation for any reader of this study.

2.1.1 Basic Idea of Process Mining

Process mining reconstructs business processes based solely on information from business source systems. No *a-priori* model is used. Source systems can be enterprise resource systems like SAP or Oracle, customer relation management systems like Salesforce, or other data sources like Google Sheets. From this data, per process, one event log is created. For traditional process mining, the event log must contain at least three specific columns: *case ID*, *activity name*, and *timestamp*. [16], [12]

Let us take an invoicing system as an example. We have a record of an invoice with a specific creation date. We can fill the event log with the *activity* "Invoice Created", the creation date as *timestamp*, and the invoice ID as *case ID*.

Using an event log, as shown in Table 1, an event graph can be reconstructed. The most common, traditional event graph is a "directly follows graph". For any case, it shows all activities on one linear path, which are connected solely based on which activity follows

case ID	activity name	time stamp
243	Invoice Created	13.01.2024 - 14:34
243	Invoice Paid	16.01.2024 - 12:23
…	…	…

Table 1: Basic activity table for traditional process mining including all required columns

the last. This means no concurrent activities can be displayed; all are shown on one line. The graph usually displays all cases with the same sequence of activities combined in the same path. Deviating variants are shown per deviation. If the second path is the same as the first except for one more activity, only the additional activity is shown on top of the first graph. [17]

The representation of Case-Centric Process Mining is often referred to as two-dimensional. Time is usually depicted as the negative y-axis, and deviations are distributed on the x-axis.

2.1.2 Practical Use of Process Mining

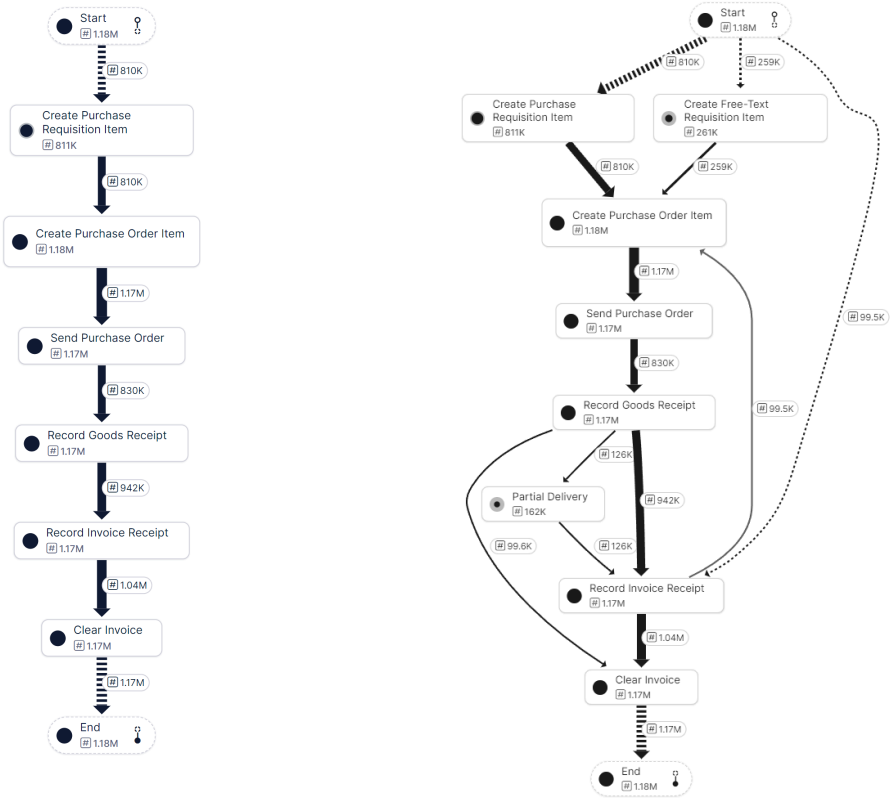
An essential part of process mining is filtering down on specific cases that represent favorable, unfavorable, or interesting process variants or activities. Therefore, supplementary tables like information about the buyer, purchased item information, or other helpful tables are added.

According to van der Aalst [18], the prominent business applications for process mining are:

1. **Process discovery:** This involves creating process models without a priori model from raw data. It helps in visualizing the actual processes.
2. **Conformance checking**: This step compares the actual process (as recorded in the event log) to a pre-existing process model. It aims to check whether real processes conform to the model and identify deviations. [19]
3. **Process enhancement:** This involves improving existing process models using information about the actual process recorded in the event logs. It can include detecting bottlenecks, redundancies, and other inefficiencies.

2.1.3 Shortcomings of Case-Centric Process Mining

Every modeling technique is just a specific, simplified representation of reality. In the traditional, Case-Centric Process Mining approach, mapping every process object to one case ID (also called case key) is the main simplification. This means one object needs to be chosen as the primary identifier, and other objects are mapped to it. Other relationships between objects are lost. [20], [18]



(a) Most common path only

(b) Most common path with five process deviations

Figure 1: Directly follow graph in Case Centric Process Mining - same process but different amount of deviations

The following example, based on a lecture by Prof. van der Aalst [21], should illustrate this.

When ordering *items* in a webshop, one *order* corresponds to many *items*, and many *items* can be sent in one *package*.

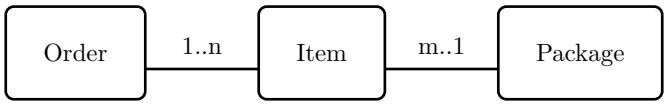


Figure 2: Correspondances between objects in the webshop example

A realistic capture of activities would incorporate multiple object types per activity. Table 2

To reconstruct the process, we must choose an object ID as our case ID. This decision will always be a trade-off on where to put a focus for correctness. Usually, the smallest, most frequent object is chosen. In our example, it would be *items*. Any activity directly

activity name	time stamp	orders	items	packages
Order placed	13.01.2024 - 14:34	{243}	{23422, 37458}	{}
Item picked	16.01.2024 - 12:23	{243}	{23453}	{}
Package sent	16.01.2024 - 12:23	{243}	{34345}	{35663}
...	...	...	...	...

Table 2: Realistic activity table partially including multiple objects per column

concerning the selected object *item* will be represented correctly. As multiple objects are involved in any process, three main issues arise.

- **Convergence:** If we also like to represent activities that happened to n-to-1 connected objects, for example, on an *order* level for "order placed", "order canceled", or similar, we will observe convergence. Even though a particular *order* is received once, in Case-Centric Process Mining, we need to create the specific activity for each contained item. Counting the number of activities of type "order received" would lead to a higher number than expected because the counter would be incremented for each connected *item* and not *order*.

activity name	time stamp	orders	items	packages
Order placed	13.01.2024 - 14:34	{243}	{23422}	{}
Order placed	13.01.2024 - 14:34	{243}	{37458}	{}
Item picked	16.01.2024 - 12:23	{243}	{23453}	{}
...	...	...	...	...

Table 3: Realistic activity table - item is used as case key which requires to duplicate some activities

- **Divergence:** If, to circumvent the problem of convergence, a more 'higher-level' object as the case key is chosen, a different issue would arise: Other objects would be considered causally related even though they are not. For example, when order ID is determined to be the case key variations that occur in items are seen to be different if the sequence is different. So, for the methodology of CCPM, an *order* where one *item* has been *sent back* and another one later has been *delivered* is different from the variant that first an *item* has been *delivered* and then another *sent back*. Even more obvious is that a variant where two *items* have been delivered would differ from a variant where three *items* have been delivered. This might sometimes be a purposeful behavior but is usually not wanted.
- **Deficiency:** Another issue is that objects that don't have a corresponding case in the new event log can not be represented. For example, the order process cannot show objects in a wish list that never become an *order item*.

Within practical applications, the issues of **convergence** and **divergence** lead to so-called “spaghetti pictures” or “spaghetti graphs” Figure 3 [22]. Both problems create unnecessary process variants, making the process representation more convoluted. While not technically wrong, the representation is now less usable.

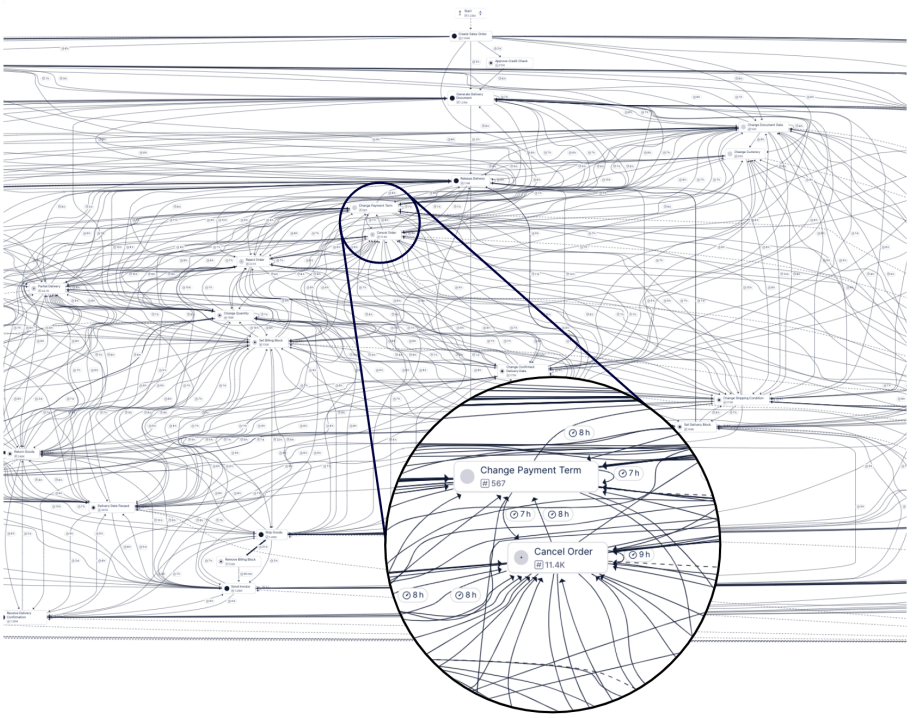


Figure 3: Case-Centric Process Mining graph - displaying all variants, also called ‘spaghetti graph’

The shortcomings of CCPM are used as trigger points in the Mixed Reality experience. They will be mentioned and shown to activate relevance for the user. It will also be shown how Object-Centric Process Mining can improve the mentioned shortcomings.

2.1.4 Object-Centric Process Mining

The main idea of Object-Centric Process Mining is adding the information of concerned objects to each logged activity in the event log. The resulting graph can be represented similarly to multiple CCPM graphs, each connected to the next, where activities happen to both objects. [23] For example, when Purchase Order Items are created within a Purchase Order from Purchase Requisition Items.

The system can add the differentiation of objects as an additional dimension. Figure 4 represents time still along the negative y-axis but objects along the x-axis. Deviations are incorporated visually, for example, by lines around a node. [20]

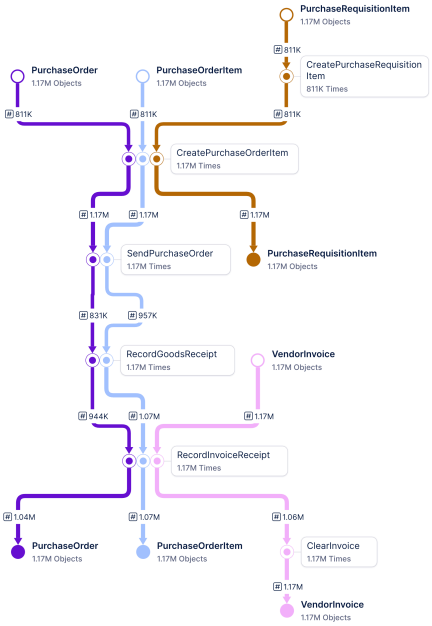


Figure 4: Object-Centric Process Mining graph - displaying most common path only, without deviations

Comparing the spaghetti graph in Figure 3 with a fully expanded OCPM graph in Figure 5, it is easy to see that the overall visual complexity is reduced.

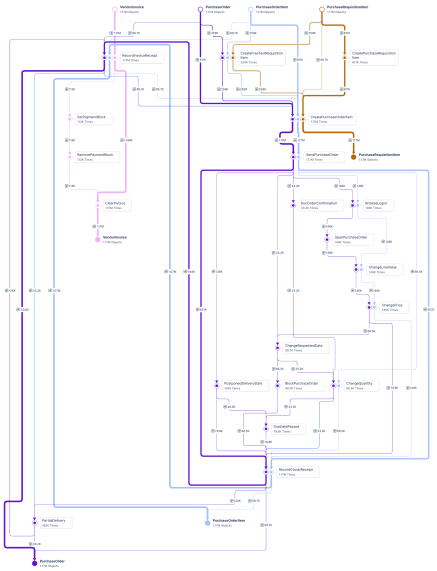


Figure 5: Object-Centric Process Mining graph - displaying all deviations

The identified shortcomings of CCPM and improvements of OCPM will be incorporated into the experience created in this study. To be more appropriate for the identified personas (see Section 4.1), more practical benefits were derived in Section 4.5.5.

2.2 Mixed Reality

For this thesis, the definition of Milgram for Mixed Reality is used [24]. Newer papers trying to define Mixed Reality, like by Speicher et al., [25], still point to this notion of the Reality-Virtuality Continuum.

Another term recently gaining new momentum is Spatial Computing, mainly driven by Apple's introduction of the Apple Vision Pro [26]. Formerly often used to describe working with map and GPS data [27], it now describes a new form of computing, namely interactions with data where the location and spatial relationship matter, making interactions with computers more natural and intuitive. [28]–[30] The term has been sparingly used in this project as the focus of the experience shifted towards a story-driven approach with little actual computing involved.

The following section outlines literature reviews and current developments in Mixed Reality to build the basis for decisions made during the development of the experience.

2.2.1 Mixed Reality in Business Sales

The literature review by Firmasyah et al. shows that Mixed Reality implementations, specifically metaverse applications, are mainly driven by marketing use cases. Existing research is predominantly qualitative, and the use of these technologies is still in its infancy. [31]

Few applications try to create similar abstract representations of software for sales interactions in MR. Looking at collections of MR case studies by Jung et al. [9], [10], it can be observed that Mixed Reality applications are principally used to represent or augment real-life objects. For example, customers can watch themselves in a mirror and try on clothes to buy - or furniture can be virtually placed in one's living room. These solutions differ from this work's goal to represent the more abstract process mining concept in Mixed Reality.

According to Rokhsaritalemi et al. [32], the main advantage and challenge of Mixed Reality applications is the increased modality of user interaction. It can help for a more natural interaction but also overwhelms inexperienced users. Moreover, the development of these applications is complicated. [32] Therefore, our study will put a specific focus on user interaction.

2.2.2 Mixed Reality in Education

As illustrated by Hamilton et al. [8], most studies show that some kinds of Mixed Reality bring significant advantages for educational use.

Furthermore, McNauthan et al. found that using abstract representations of concepts can significantly improve information retention. [33] Using gamified learning in VR seems to positively impact engagement and enjoyability. [34]

These findings support the goal of this study to use abstract representations in a gamified experience to help retain information about the Celonis product.

2.2.3 Mixed Reality and Process Mining

Traditional process mining has been tried to be implemented in VR by Wetzel [35] building on Eichhorn [36] in 2022, in collaboration with Capgemini. Celonis software was used to provide the data model.

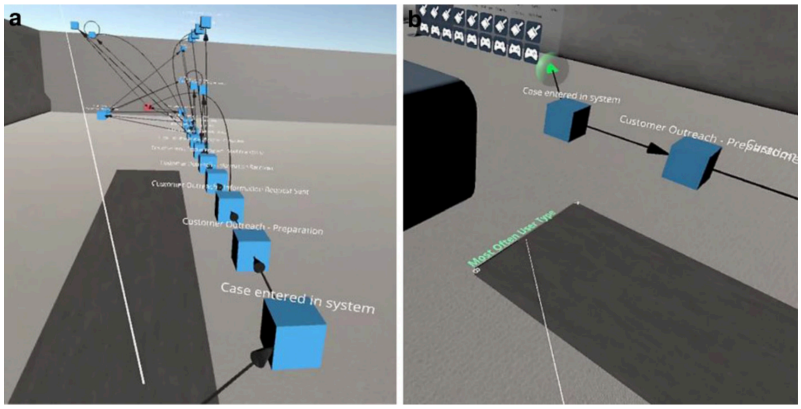


Figure 6: Process explorer represented in Virtual Reality implemented by Wetzel [35] - using the third dimension to display additional KPI values

The software can display basic process graphs and use the 3rd dimension for additional attributes of the activities like 'case count' or 'most often team'. It furthermore allows filtering on variants. The application does not seem to have been developed further. Capgemini utilized the application a few times for sales showcases, but it fell out of use quickly.

The project describes a direction this thesis could have gone into, but the low utilization and little usage support the approach of this thesis to focus on a story sales approach.

3 Methodology

The main goal of this thesis is to iteratively build and evaluate a Mixed Reality experience in a formative study that will benefit sales interactions with Celonis prospects.

The project follows the User-Centered Design framework coined by Norman and is part of ISO 9241-210 [37]–[39, Section 6.1]. They describe four main steps: *understanding* users and the environment, *specifying requirements*, *building prototypes*, and *evaluating* the prototypes against the requirements. Phases are iterated upon multiple times.

Understand: First, the needs and specifics of users and stakeholders need to be understood. Preliminary interviews with Celonis stakeholders and researchers were conducted. This has been done to build an understanding of the current possibilities and advances in Virtual and Mixed Reality, the status and goals of Object Centric Process Mining (OCPM) and the content of recent sales interactions for selling OCPM. Even though Celonis is a young tech company [40], the interviews showed that there is still little awareness about current developments in Mixed Reality advances. Therefore, at the beginning of the project, a community event was hosted at Celonis with an introductory talk about the "State of VR" and provided ample opportunities to test old and new Virtual, Augmented, and Mixed Reality headsets. This helped to foster collaboration and support for the project. Following Cooper [41], we created personas through workshops with the sales team at Celonis, anchoring the study's direction around user-centric narratives.

Specify requirements: Building on the gained understanding, following Schoen [42] and Lamsweerde [43], requirements were set together with the main stakeholders through interviews and workshops. This phase also included headset and software benchmarking.

Build prototypes: Multiple prototypes were created to test assumptions and address open questions before starting with the final product. All prototypes were built in Unity on different MR headsets. First, vertical prototypes were used for viability studies to validate assumptions of specific functions and setups. The results were also used for the headset evaluation and sharpened the requirements for the final product. Then, the final experience prototype was created in multiple iterations.

Evaluate: The vertical prototypes were directly evaluated together with Celonis employees. Formal User testing with employees, partners, and customers was conducted for the final prototype. Employees and partners participated in a more extensive test with quantitative questions, a standardized INTUI survey, and an interview. The customers were observed with a fly-on-the-wall technique. The experience was tested for its level of excitement creation and educational value. The goal was to identify required improvements and suggest the next steps.

4 Development

4.1 Personas

To start the development process with a clear focus on the right user group, personas were created. The focus of this thesis is aimed at visitors of Executive Briefing Centers.

As investments into Celonis software are very strategic, visitors of EBCs are often very senior personnel on (Senior) Vice President level or above.

An additional group of visitors includes Celonis Partners. Partner companies are consultancies that sell, implement, or help use Celonis software at a third-party company.

For this version of the experience, two main personas following Cooper [41] were created.

4.1.1 Sieglinde C-Level

The primary persona is a very senior decision-maker of the prospect company. Potential titles are C-Level, like Chief Information Officer, Chief Data Officer, and Chief Financial Officer, or Vice-President-Level of a medium to large-sized company.

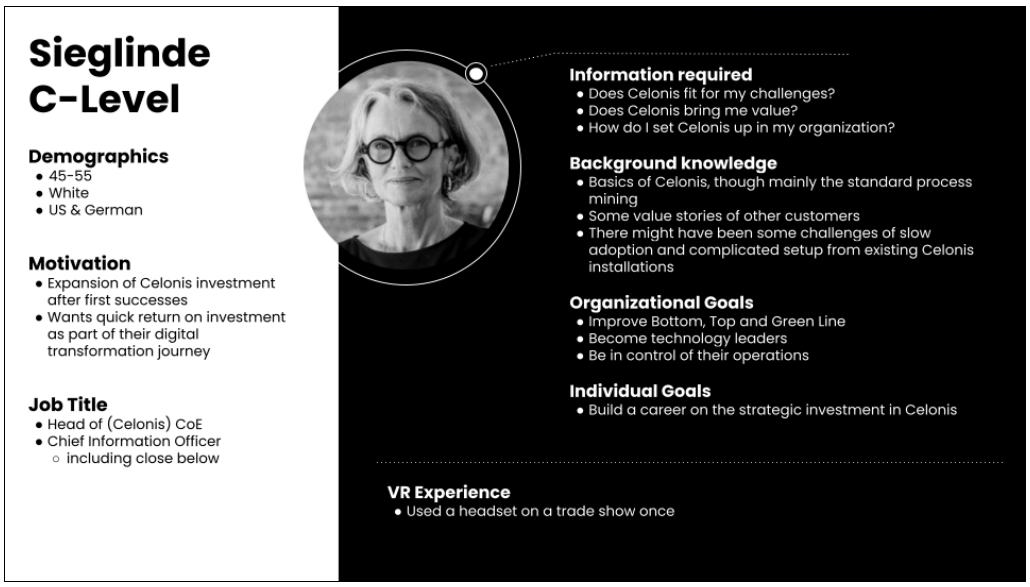


Figure 7: Persona card - Sieglinde C-Level

- Their goal is to evaluate additional investment in Celonis after their first successes to leverage a quick return on investments as part of their digital transformation journey.
- They need to understand on a high level how Celonis can bring them value and how well they can set it up within their organization. Technical details are not of their concern.

- They commonly have basic Celonis knowledge, usually based on traditional process mining, from the existing relationship with Celonis. The level of understanding is more on overall business implications than an understanding of the workings of the software.
- Sometimes, they face challenges of slow adoption and complicated setup of existing Celonis installations.
- Organizational goals are to increase their revenue, reduce cost, improve their sustainability, become technology leaders, and be in control of their operations.
- Their goal as an individual is to build a career on the strategic investment in Celonis.
- Due to the persona's age of 45 to 55 years and high position, we provisionally assume their VR headset experience is very low, and they might only have worn a headset briefly. This assumption has been made together with sales experts.

4.1.2 Constantin Consultant

The secondary target group for the EBC and the experience are Celonis partners. Partners are consultancy companies that sell, implement, or use Celonis.

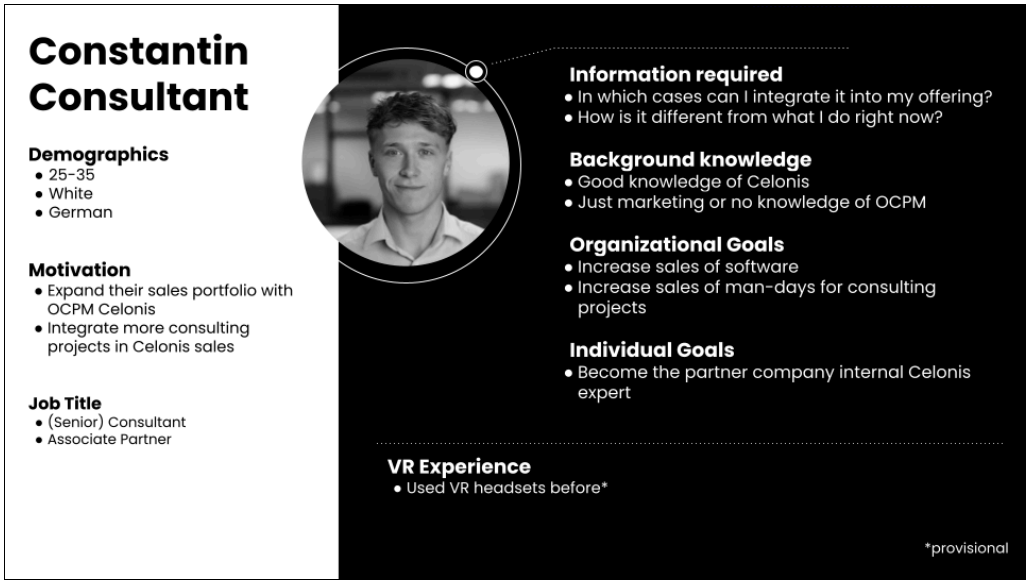


Figure 8: Persona card - Constantin Consultant

- The partners want to expand their sales portfolio with OCPM-driven Celonis.
- They already have good knowledge about traditional Celonis but need to stay updated with new developments.
- OCPM is something they read marketing material about but did not explore in detail.
- The consultants want to find new ways to sell their offerings.

- They are 25-35 years old and technically inclined, which we provisionally assume gives them some experience with Virtual and Mixed Reality headsets.

4.1.3 Implications of Personas

The personas created imply multiple considerations for the story to be created, as well as for the interactions and user experience within the headset.

The main persona is business-oriented and not technical. They usually do not work with the software directly. This means that also the experience will have to be about business advantages and not focus on the tool or visualization itself. Technical details need to be translated into business implications.

Due to the higher age of the main persona and the presumably little experience with head-mounted devices, the experience should be effortless to use and require little pre-knowledge. Effects like motion sickness need to be reduced to a minimum.

The high seniority also means their time is precious, so the experience should be short. This also implies minimal setup time with the user and only short tutorials within the headset.

The second persona generally sets less strong requirements. For development focus, it is mostly encapsuled within the first persona. Nevertheless, the partner persona must be considered for testing and rollout purposes.

These implications were added to the requirements and influenced the decisions made for the final prototype. The application might also be utilized with other user groups, but the experience does not need to be specifically designed for those.

4.2 Requirements

After building the personas, a list of requirements was created to capture findings from the interviews, personas, and general guidelines. The final list comprises 33 elements and includes requirements by the EBC team, the academic adviser, the Chief Design Officer, and the Vice President of Product Marketing.

The requirements were clustered by type into *functional* (functions/requirements that the system should perform) and *non-functional* (the quality attributes of these functions) [44]. Every point received a priority following the "MoSCoW" scheme by Clegg [45]. This includes *must-have*, *should-have*, *could-have* and *will-not-have*.

A few examples of requirements that primarily shaped the experience are:

Functional Requirements

- **Business relevance:** The content should be relevant to business executives, not technical. The focus is on business advantages, not implementation details.
- **General applicability:** The experience must apply to a diverse set of companies and users. It should not require specific data or information about the customer to make it work.
- **Interactivity:** The experience should allow users to interact with the virtual environment to enhance user engagement and content retention rates.
- **OCPM graph representation:** There should be an abstract representation of an OCPM graph to understand how it is better than the normal graph. This should also reference our marketing material and bridge the gap to the real product.
- **Spatial audio:** The experience should include spatial audio.
- **Educate around OCPM:** The Experience should help to understand OCPM better.
- **Language support:** The experience will not support multiple languages.

Non-Functional Requirements

- **Memorable experience:** The experience should be something special to remember.
- **Experience length:** The experience should be long enough to teach important aspects but not too long to hold back the flow of the EBC.
- **Low maintenance:** The experience should require low maintenance by the EBC team to be run.
- **Color scheme:** The experience should follow the Celonis brand aesthetics: predominantly feature black and white, abstract, and minimalistic.
- **Ease of use:** A broad range of users should be able to experience the application without issues or feeling uncomfortable.
- **Maximum runtime:** The experience should have a maximum runtime, for example, by preventing users from replaying sections. This will allow for a smooth continuation of the EBC visit.
- **Comfortable view area:** The view area should rather be a panorama and not include content above or below a certain range to be easier to view
- **Outside guidance not needed:** The experience should be usable without outside guidance.

The requirements were followed during development and helped to check the progress after testing prototypes. [42], [43]

4.3 Vertical Prototypes

After understanding the problem and formulating the requirements, multiple prototypes were created and tested to evaluate the viability of arising assumptions and possible functionality. These include how users react to Virtual vs Mixed Reality, eye tracking, hand tracking, and technical setup. The tests were designed to discover preferences and issues as quickly as possible. All vertical prototypes were tested on the Meta Quest Pro.

4.3.1 Virtual vs. Mixed Reality

At the time of starting this study, Virtual Reality devices began to offer high-quality video passthrough at affordable prices. We tested how users would react to the same scene experienced in video pass-through Mixed Reality vs Virtual Reality mode to decide on the overall approach for the final prototype.

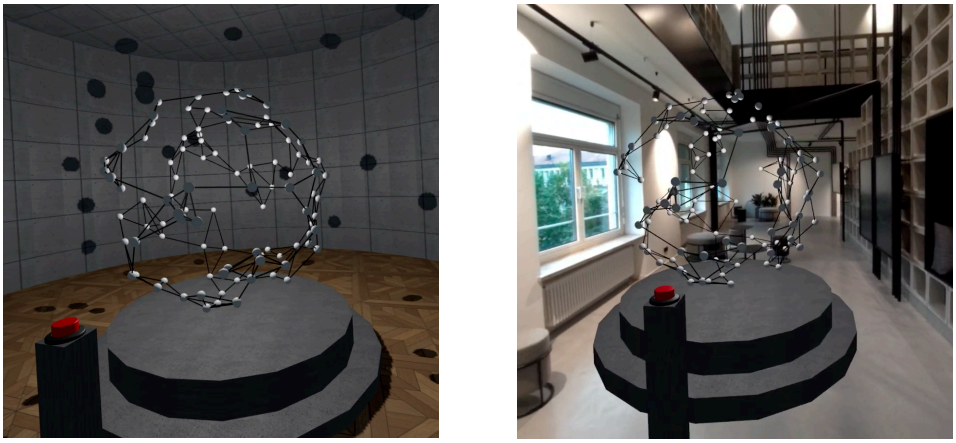


Figure 9: Same test scene experienced as a virtual room or using passthrough.

The nine participants could switch between the two rooms at their own will by activating a button. They were tasked to walk around the scene and voice their experience. The guard system for the Virtual Reality Mode, visualizing the boundaries of the real world, was activated and introduced.

The main differences mentioned were that Virtual Reality felt more immersive and captivating, whereas the users felt much safer in the Mixed Reality environment and moved around more freely. Also, Mixed Reality was perceived as more novel and special.

When asked about general preference between virtual and mixed reality, the results in Figure 10 show a bimodal distribution with preferences for extremes.

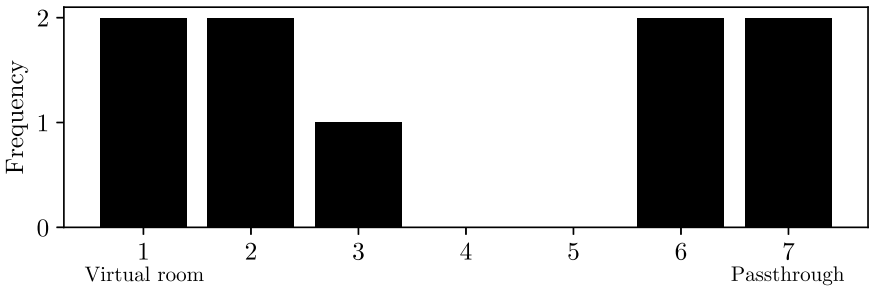


Figure 10: Results of question “Which version of the room did you prefer?”.

Due to these results, the final experience is predominantly built in Mixed Reality to make users feel more secure and allow for more free movement. Virtual Reality is used as a short-term emphasis to utilize the immersive factor. The added feeling of security helps fulfill the main persona’s requirements.

4.3.2 Eye Tracking

Apple Vision Pro was announced to work with eye tracking as a primary input method. The implementation has been called ‘awe-inspiring’ by testers [46]. For that reason, we wanted to experiment with it.

At the time of testing, the Vision Pro was unavailable, so the Meta Quest Pro was used to assess eye tracking. The users were shown targets to be selected with their eyes (see Figure 11). Different target sizes and spacings were compared.

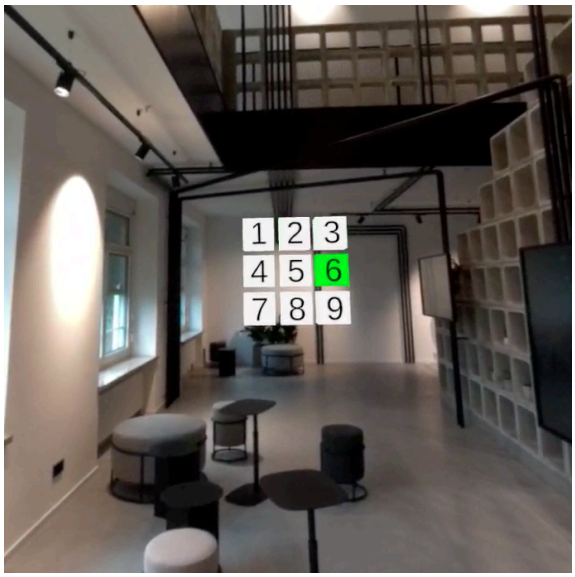


Figure 11: Eye tracking test scene - participants were asked to select numbers by looking at them and reporting their experience.

Even though some described the experience as magical, tracking errors on small targets evoked mixed opinions.

Targets could only be tracked precisely after recalibration of the device, and the final setup would not allow for this due to time constraints. This is why eye tracking was left out of the final experience.

4.3.3 Hand Tracking

Hand tracking could provide an easier-to-learn input method than controllers as long as grabbing objects feels natural and reliable. Therefore, we created a scene where users were asked to grab different objects using hand tracking to see whether it should be used as our input method.

The test showed that participants grabbed very differently from one another. This is also influenced by the size and shape of the object to grab.

Within the Meta XR Interaction SDK, two main grab methods are available. *Grab* and *touch hand grab*. The former triggers the grab when a grab gesture is recognized, for example, the thumb and index finger touch. The latter uses a rigidbody-hand where each hand section realistically interacts with the object's shape. Whereas the *grab* interaction provided better reliability when moving objects fast, the *touch hand grab* triggered the grab earlier in the grabbing movement helpful for some grabbing techniques used by novice users.

(a) 'Grab' (b) 'Touch hand grab' - rigid body hand

Figure 12: Comparing different grab implementations using Meta interaction SDK.

Ultimately, both grab techniques were combined with small objects built out of simple shapes. This received consistent feedback that grabbing was intuitive, easy to learn, and reliable.

4.3.4 Technical Prototype

Lastly, a prototype telling a simple story was created to test code structures and methodologies. This proved very beneficial to build expertise in Unity development and Virtual Reality scenes. The resulting technical setup was used in the final prototype, see Section 4.5.1.

4.4 Headset Evaluation

Based on the list of requirements for the experience and results of the vertical prototypes, different Virtual and Mixed Reality headsets were compared. A simple list of requirements ranked by importance was formed. This included inside-out tracking for easy setup, support for prescription glasses, high resolution, compute performance, etc.

After inquiring with vendors like Varjo, Meta, Pico, Schenker Technology, and VR Experts, the most promising headsets were rented and tested for usability and reliability. This included the Pico 4e, the Meta Quest Pro, and the HTC Focus 3. Following up on the good test results with the Quest Pro, the newly released Meta Quest 3 was chosen. It was selected because of its great video pass-through, ability to quickly accommodate prescription glasses, low price, stable platform, and established development tools.

4.5 Main Experience

The main experience was created in multiple iterations to find suitable interactions, memorable learnings and understandable explanations. The user progresses through a linear story by interacting with digital representations. The interactions and visual representations in space should help recall important business advantages of OCPM.

The full story walkthrough is available as an appendix. The most important experiments, decisions, and results are shown in the following section.

4.5.1 Technical Implementation

The development platform Unity 2023.1.16f1 was chosen, and the app runs standalone on the headset. The Unity Meta XR SDK was used instead of OpenXR to deploy the newest features like advanced hand tracking, scene management, and text-to-speech. The decision for specific instead of general framework should pose no problem because usage will be exclusively on Meta headsets. The code architecture followed a model-view-controller architecture to separate logic and make the code more readable. The main controller includes a simple state machine to progress flexibly through the story.

An important advantage of using Mixed Reality in a fixed room setup is to place virtual objects logically and aesthetically with real-world objects. To do so, scene anchors are

placed during room setup to mark the locations and orientation of walls. During usage, the Quest headset can remember the room and orient all objects centrally, free of obstruction, and comfortably accessible.

4.5.2 Story Approach

Using a linear story for the final prototype was just one of the possible approaches to convey the requried learnings to the audience. Other considerations were a specific, detailed representation and user interaction with OCPM that illustrates its advantages or to create a virtual world that represents a shopfloor through which users can virtually walk through and see information annotated by OCPM.

The linear narrative approach was chosen because the installation must be universally understandable and applicable to various audiences. It allows flexibly extending and adapting different learning sections during development and beyond.

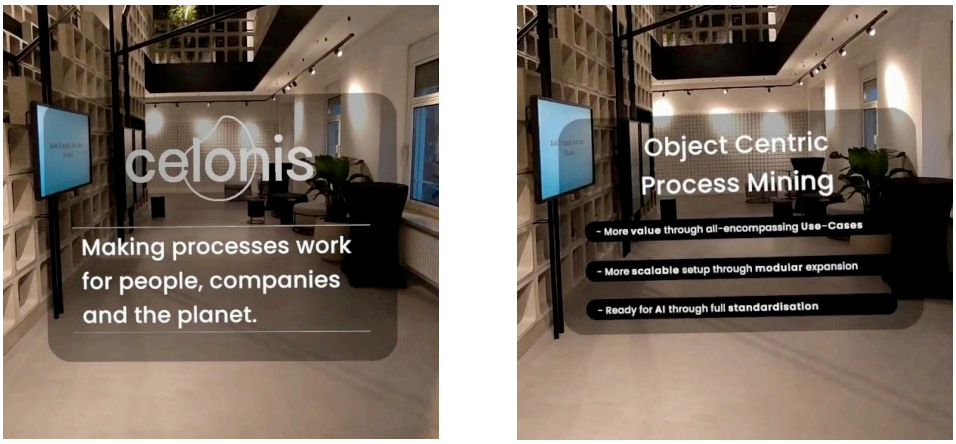
An invisible narrator guides through the sections. A competent sounding female voice through the Meta text-to-speech service was deployed.

After a short intro, the story revolves around three main advantages:

1. “More value through all-encompassing use-cases.”
2. “More scalable setup through modular expansion.”
3. “Ready for AI through full standardization.”

4.5.3 Introduction Design

To start the experience as comfortable and welcoming as possible, the first few seconds are spent on an overview of the story and the business advantages of OCPM.



(a) Start screen (b) Learning goal

Figure 13: Soft introduction to the experience by displaying simple 2d elements in front of the participant.

The user is prompted to take their time, move around, explore, and consider taking a step back to see the full picture. This initial prompt has been shown to take off pressure and evoke a more explorative approach for the participants.

The installation then slowly opens up by placing objects within the room and prompting the user to walk around.

4.5.4 Object Placement and Scene Understanding

To support the story, the representations of the customer's company, their source system, and the Celonis system are mapped out in a half-circle around the user. This shall help to create a mental image of what is being shown. The order is how data would flow from left to right. The elements are sequentially introduced one by one. On the free side, to the user's right, the learnings panel is placed in the middle of a wall.

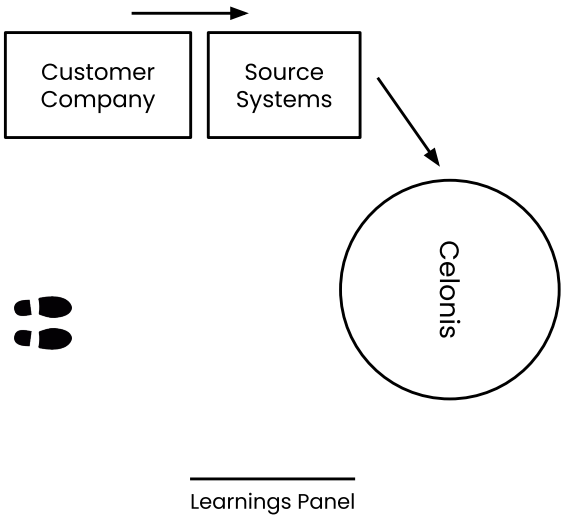
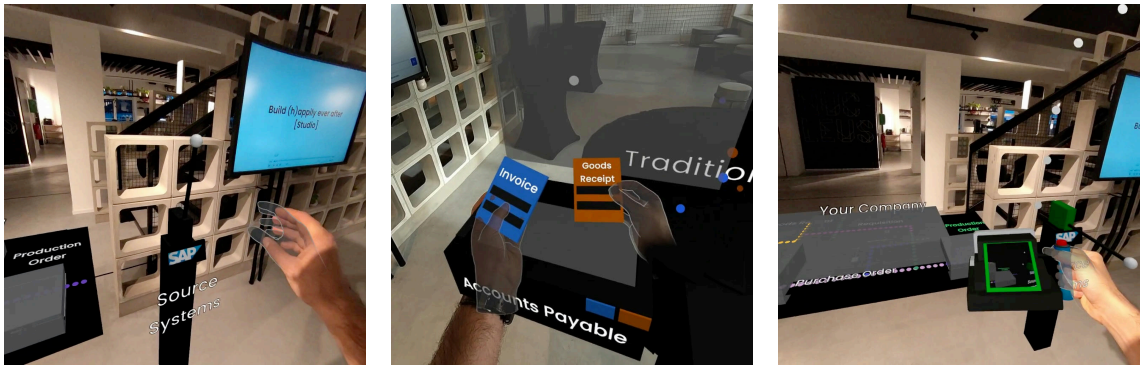


Figure 14: Schematic top-down view - arrows illustrating data flow

To enforce the mental image of the representation, interactions were added to improve or test the users' understanding.

(a) **Connecting source systems** by pulling a lever.
(b) **Fueling the Celonis machine with objects** by placing representations into baskets.
(c) **Going back to your company** to take a picture of the missing object.



(a) Pull lever of source system (b) Grab objects to add (c) Take a picture of company

Figure 15: Interaction examples improving the participants understanding of the story.

4.5.5 Illustrating Business Advantages of OCPM

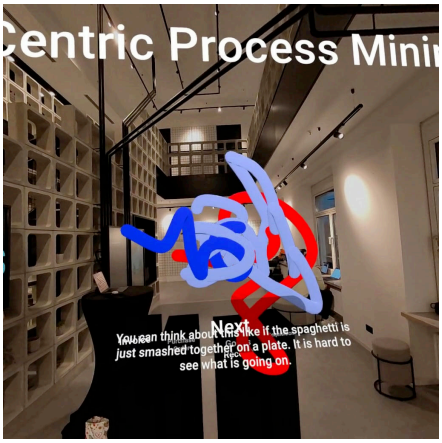
The following advantages were elicited from the interviews with product marketing and sales. This section explains how they were integrated into the story and enforced through interactive elements.

4.5.5.1 Additional Use-Cases

The first learning shows how Object-Centric Process Mining can leverage additional use cases. Use cases in process mining are improvement opportunities that surface through process visualization and additional information. Whilst CCPM must display processes separate from each other, OCPM can display connections across multiple processes. Therefore, new use cases where issues in one process affect other processes can now be discovered.

If CCPM tried to span multiple processes by connecting objects with a common case key, the issues of convergence and divergence (see Section 2.1.3) would create unreadable spaghetti graphs quickly, and the deficiency issue would drop cases where no connection can be made.

In earlier iterations of the story, illustrated in Figure 16 this fact was displayed as spaghetti connections being untangled by introducing a third dimension.



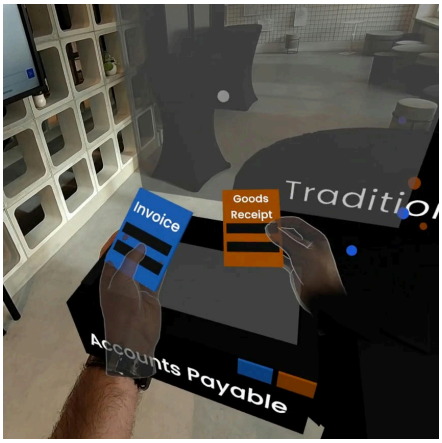
(a) Representation of graph seen through CCPM

(b) Representation of graph seen through OCPM

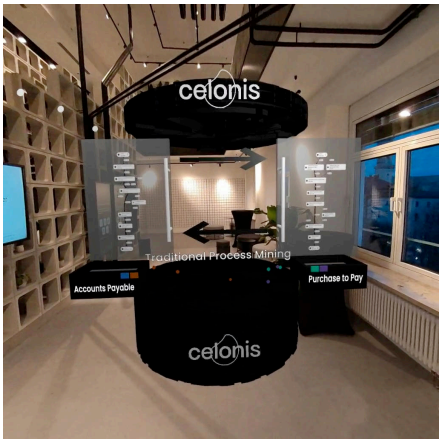
Figure 16: Story illustrating untangling spaghetti graph through the third dimension - was not used in the final product.

This illustration was commonly misunderstood and consequently not included.

In the final prototype (see Figure 18), the additional possible use cases were illustrated by displaying two processes in CCPM. The user is required to add objects to exactly one of those processes. Adding all objects to one screen does not work. In the created processes, one process displays an issue, but the reason for this issue is somewhere in the other process.



(a) Adding objects to correct process



(b) Two CCPM processes separate from each other

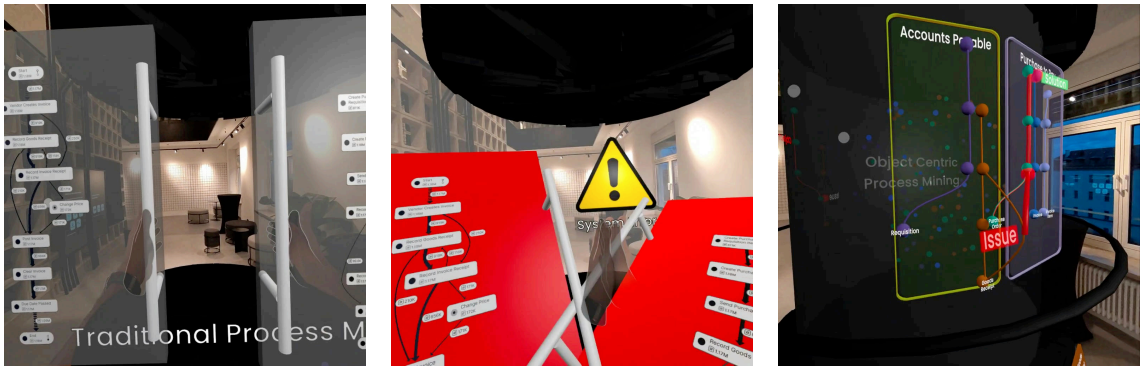
Figure 17: Story illustrating that in Case Centric Process Mining the processes have to be analyzed separately from each other.

Then, the user is asked to bring the two screens together to find the connection, but this will lead to a mocked-up system error.

During the development, two different versions were tested: Bringing the screen together by pushing a button as well as pulling them with both hands using handles.

The button interaction could help the user dissociate their action from the resulting error so they would not feel responsible for what happens. This could lead to more positive emotions. While this might be true, pulling the screens directly using handles was perceived as a particularly fun interaction and was chosen for the final installation.

To overcome the system error, OCPM needs to be used. This allows the system to connect the processes and show the full picture, where the issue and solution can be shown together.



(a) Trying to find use case connection (b) CCPM system error (c) OCPM connecting processes

Figure 18: Story illustrating that there are use cases are only possible in OCPM, not CCPM

To make this point more intense and immersive, first, the pulling interaction is artificially made harder to increase the user's attention. As soon as the screens touch, an error sound is loudly played. The screens immediately become red and fall to the floor. The user is immersed in a white room in Virtual Reality for a few seconds to utilize the effect discovered in Section 4.3.1.

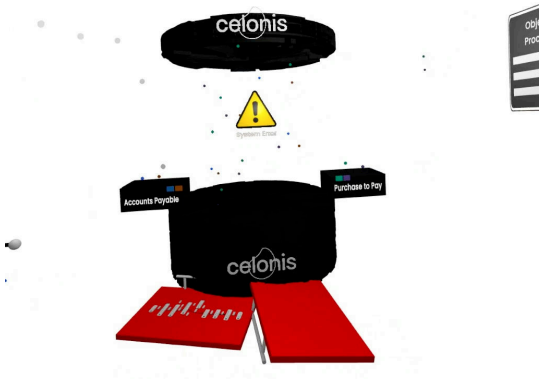


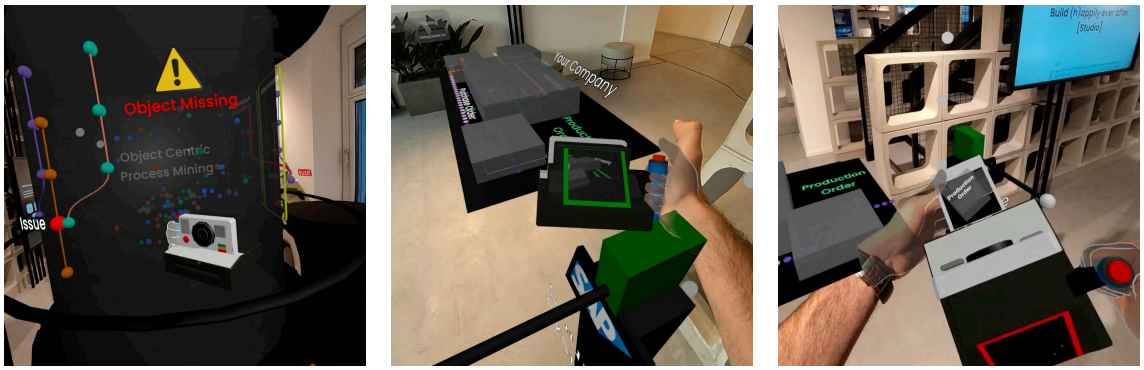
Figure 19: Enhancing immersion with short-term Virtual Reality by replacing the passthrough with a white room for a few seconds.

4.5.5.2 Flexible Expansion

The next learning is about data models. In traditional CCPM, every process is in a separate data model. A single object can take part in multiple processes. Therefore, when activities of a new object are added to the system, they need to be added to all data models through custom SQL transformations, which can require multiple data scientist man days of effort. In OCPM, adding additional objects is much simpler as just one huge data model is used. OCPM also needs less to no SQL transformations to do so.

To illustrate this point in the experience, the user must pick up a Polaroid camera and take a picture of an object to be added to the system. The picture taken then shows an abstract stereotype of the captured object, which is added to the Celonis data model. This expands the process graph displayed in Celonis immediately.

The Polaraid camera is used to illustrate the simplicity and speed of adding the object. The object being display as a hologram on the Polaroid picture illustrates the archetypical meta charater of the created representation. It is not one specific type of the object but a generalized form. The picture is furthermore taken directly of the company instead of the source systems, this represents the fact that the created object representation is disjunct from its form within the source system.



(a) Missing object in OCPM (b) Taking picture of object in company (c) Using the created meta object

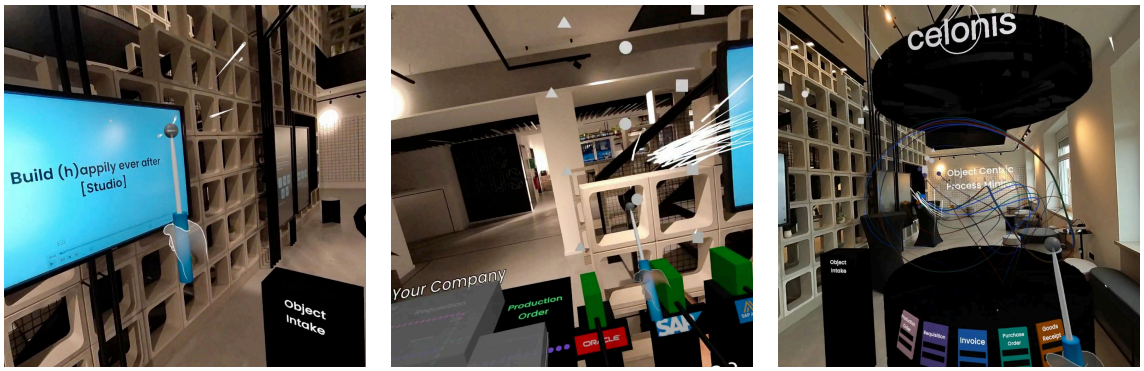
Figure 20: Story illustrating modular expansion of the data model.

4.5.5.3 AI Compatibility

The last learning is devoted to artificial intelligence (AI). AI can be trained and applied more effectively on standardized data sets. The new OCPM data model is standardized across all dimensions, like source systems or processes. This allows AI applications to be more effective and robust.

To introduce AI playfully, a magic wand was implemented. The wand can interact with data and *enhance* it. This is represented by trails following the data points floating around in the Celonis machine. To illustrate how AI works better on OCPM than on the source

systems, the magic wand can not add trails to data directly from the source systems but to the data in OCPM Celonis, as seen in Figure 21. The narrator explains the underlying reasoning.



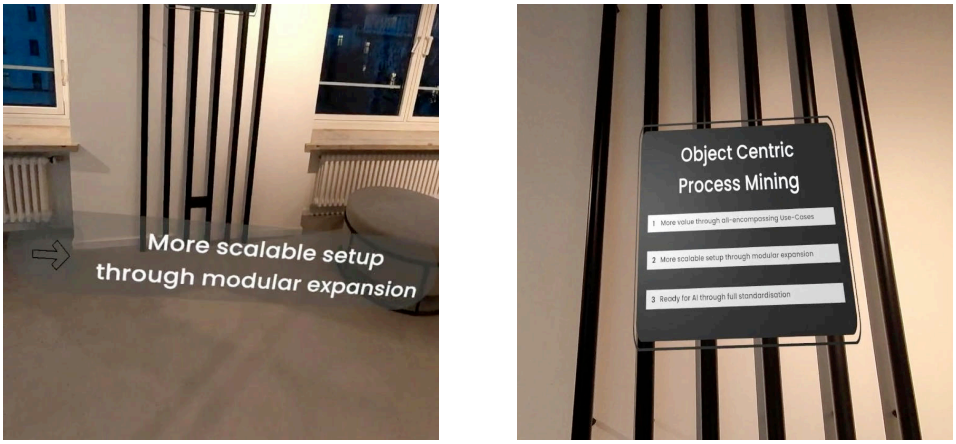
(a) AI represented as magic wand (b) Failing to add AI to source system (c) Enriching OCPM data with AI

Figure 21: Story illustrating trying to add AI to source systems or OCPM.

As this is the last learning of the story, the section is meant to activate the user to end the experience with excitement and on a positive note. From this point on, as long as the wand is held, a force field attracts the data points that now have long trails. Moving the wand creates data points with trails around the user, immersing them in the experience. Once the user let's go of the wand, the data returns to the Celonis representation.

4.5.6 Learning Illustrations

As the learnings pose a vital part of the experience, multiple measures were taken to enforce them. Initially, the learnings are quickly outlined to give the participant a rough overview. After each of the three learning sections, the key message is shown as a learning piece in front of the user and moved to a big learning board.



(a) Learning snippet displayed after each section (b) Learning panel where learnings are added

Figure 22: Learnings displayed in the experience.

This showed multiple advantages: It structures the experience, slows users to think about what was shown, indicates how far along the experience is, and helps formalize and remember the intended learnings.

4.5.7 Interaction Signifiers

Ghost hands are added as signifiers to objects that afford to be grabbed or interacted with. For example, a grab-and-pull animation to turn the Celonis representation around its vertical axis (Figure 23(a)). Furthermore, if only a specific part of the object is grabbable, this part is highlighted with a blue material (Figure 23(b)).

(a) Indicating turnwheel (b) Indicating camera grab

Figure 23: Ghost hand and indicative, blue material to show interactability.

4.6 Challenges

The following section illustrates a few additional challenges encountered during the development.

Accessibility: Iterative testing with particularly tall or short people showed substantial ergonomic differences when the user tried to interact with elements that would be placed too high or low to be comfortably reachable. The users did not explicitly mention this, presumably because the same issues are encountered in real-world installations.

For the virtual installation, an automatic height adjustment was implemented. When pressing the start button, the headset calculates the user's height and adjusts the interaction elements accordingly. This should even allow wheelchair users to experience the story comfortably.

Avoid suggesting affordances that are not possible: A problematic phenomenon surfaced when developing and testing the OCPM representation. When the representation of the process graph for OCPM and CCPM became higher fidelity, users started to

want to interact with it more. The more the graph looked like a product, the more the users wanted to select, zoom, or manipulate parts of it and were disappointed when it was not currently possible. As there was not enough time to develop the missing features, a simpler, more abstract representation was chosen, which satisfied the users more as they were less disappointed.

Subtitles: The placement of the subtitles posed a particular challenge. The main challenge is to place the subtitles floating comfortably and always available while not obscuring objects.

Multiple studies have tried to evaluate options, but the consensus is that they depend heavily on the experience, and no universally applicable best practice exists. [47]–[49]

Additional research and testing should be conducted; this should also improve issues with cognitive overload. Until then, the floating subtitles can be turned off and placed behind the user.

Finding the proper technical depth: Explaining structural differences between CCPM and OCPM seems to require technical explanations, which proved too technical for the target group. The now-used, more technically shallow, and business-oriented explanation does not satisfy technical people. Finding the correct depth is a balancing act and cannot satisfy all user groups with the same experience.

Developing for standalone headset applications: Unity applications for Quest headsets usually need to be packaged as an Android package and transferred to the headset to run. This is the only way when developing on a Mac. Using a Windows machine, the Meta Quest Link can run applications directly from the PC without packaging an app first, practically creating a PCVR setup where the screen images are streamed to the headset from the PC. This sped up development times. Important issues to look out for are significant differences between running in PCVR mode or exclusively on the headset. The PC's performance is usually way better than on the headset; this could lead to developing and testing too complex scenes and shaders over the link, to realize later that the headset cannot run the application smoothly anymore. Also, shaders behave differently when running on Android vs PC.

Developing spatial experiences from a remote building: The experience can use a lot of space in the Celonis headquarters, eliminating the need to move the player relative to the virtual environment. For example, by using translation or teleportation. However, the application was developed in work-from-home in a smaller room because the development machine was a desktop PC. Issues were partially circumvented by integrating debugging features to translate the objects within the room using the PCVR connection.

At the time of development, the headset could only store one room setup and had to be set up again whenever transported to a new location. Also, changing light conditions or rearranging furniture could prevent the recognition of the roon. Meta since seems to have fixed both issues with a new update.

Working with experimental beta features: The experience uses experimental features of the Quest headset, like advanced hand tracking and room layout. As was to be expected, changes to the SDKs during development required some reimplementation of features.

Debugging a long-running story: Since the application consists of a linear narrative, debugging specific interactions could take a long time if the application must be run through at normal speeds. Commenting out unnecessary code sections can prove not feasible when testing must be done in the office and not next to the development PC. To improve this, a hidden menu has been implemented, accessible within the standalone implementation of the app. It allows one to jump to specific story sections and skip the narrator's texts.

5 Evaluation

The evaluation is a formative study to indicate if the sales experience can provide excitement and learning to senior decision-makers. It should furthermore determine what concrete steps can be taken to build the final installation.

5.1 Ethical Considerations

The user tests were considered to pose a low risk for the participants. Cybersickness was persistently reported as extremely low or non-existent, and all tests were conducted with consenting adults voluntarily participating.

Therefore, standard measures were taken to protect personal information by anonymization of recorded data. Participants were informed and consented to risks like cybersickness and epilepsy. Videos were recorded in such a way as to not show participants' faces.

5.2 Methodology

Two main evaluation formats were applied. A structured, extensive user test for 45 minutes per person on Celonis employees and partners. Further insights were gathered while the experience was used with actual visiting customers.

While the former included qualitative pre- and post-surveys and a detailed guided interview, the latter was just done using the fly-on-the-wall technique. This means observing while the customers went through the experience and only having a short, casual feedback talk afterward.

Within the extensive test, the pre-survey included basic demographic questions and asked about familiarity with Virtual Reality headsets and OCPM. Moreover, one pre-test/post-test design question was included about how comfortable participants were with explaining OCPM to colleagues to indicate perceived learning.

After the pre-survey, the subject was asked to put on and adjust the headset independently and enjoy the self-paced experience.

The following post-survey had multiple questions about impressions of the experience and the perceived maturity. All questions which allowed for a scaled answer used a 7-point Likert scale with adapted wording like "not at all" to "very much". This makes it the same scale as the additionally used INTUI questionaire.

The INTUI questionnaire by Ullrich and Diefenbach [50] measures different dimensions of intuitiveness. It also offered a good way to make the results comparable. The INTUI score fits better to the experience's focus on excitement and ease-of-use, than more com-

monly used scores like the SUS [51]. Depending on the mother tongue, it was presented in English or German.

Answers in the questionnaire were picked up in an open interview discussion, together with asking about positive and negative aspects and improvement opportunities.

5.3 Demographics

As the first target group is senior-level prospects, they represent a critical group for Celonis, and every official interaction is done very cautiously. Therefore, the main, long user tests were done with approximate target group representatives and stakeholders within Celonis. The second target group, partners of Celonis, were more accessible to approach and invite.

Eleven Celonis employees and four Celonis partners participated in the more extensive tests. Four customer prospects participated in the fly-on-the-wall tests.

- **Seniority level:** The tested group included multiple (senior) vice presidents, team leads, one C-level, and one general manager. With 47%, almost half of the participants were managers or above.
- **Familiarity with headsets:** The average self-assessment on the familiarity with Mixed or Virtual Reality headsets was 3,47 (std-dev: 1.68) on a 7-point scale, which is slightly below neutral.
- **Age:** The participants ranged from 23 to 48 (avg 30.6, standard deviation 6.27).*
- **Sex:** 21.1% female, 78.9% male
- **Colorblindness and stereo vision:** None of the participants was color blind. Two participants answered that they could not see stereo or didn't know. *
- **Familiarity with OCPM:** The participants reported an above-neutral proficiency in OCPM with a reported average of 4.6 (std-dev: 1.64), and seven people answered with six on a 7-point Likert scale. *

** dimensions indicated with a star only include data of the full user-tests*

The tested group has an adequate senior representation but is younger and more proficient with headsets than the target persona. This could bias the results. Any issues in this regard, like being overwhelmed, needing time to adjust, or cybersickness, need to be evaluated carefully.

5.4 Results

5.4.1 Quantitative

The experience was rated highly overall (avg. 6.53, std-dev. 0.52), with the lowest rating of 6 on a 7-point Likert Scale. 73% answered they learned something in the experience by rating with five or higher (avg. 4.87, std-dev 1.85). The average of how confident the participants felt after the experience explaining OCPM rose by 0.4 points. 93% answered with five or higher that in addition to the current state, the experience should be considered to be developed further. Also, 93% would likely allocate headcount to investigate Mixed Reality for Celonis. All participants responded that they think the experience can be shown, in the state it currently is, to customers, partners, or Celonis employees.

The experience seems to be very effective in creating excitement. However, the story does not seem detailed enough to explain OCPM to its full length. Furthermore, Celonis employees and partners support expanding on and investing money in Mixed Reality.

The collected INTUI test results allow for comparing the experience to other products. The original paper [50] provides mean values for categories like computers, mobile phones, home appliances, and fun products. Our experience achieved higher mean values than any other product for *gut feeling* (mean: 3.82, std-dev: 1.10) and *magical experience* (mean: 5.88, std-dev: 0.74), as well as on average values for *effortlessness* (mean: 5.04, std-dev: 1.03) and *verbalization* (mean: 5.6, std-dev: 1.49). The paper of Ullrich [50] does not provide comparison values for *intuition* (mean: 5.4, std-dev: 0.99). Note that due to the low number of participants, these numbers serve as an indication and do not try to explain with statistical relevance.

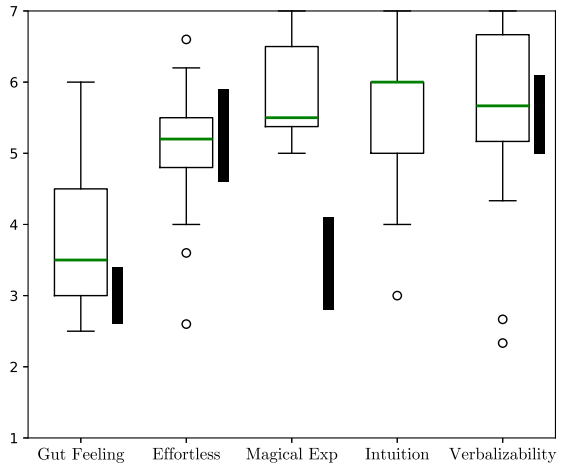


Figure 24: Boxplot of INTUI results - green lines represent mean values of the experience, black bars represent mean value ranges of other products provided by Ullrich [50], no values were provided for intuition.

5.4.2 Qualitative

During the interview, multiple noteworthy topics emerged:

a) Natural Interactions: The interactions with elements in the installation using hand-tracking were described as *"super intuitive"*, *"easy"*, *"fun, especially for someone not used to XR"*, and *"pulling the two screens together was really cool"*. During the experience, all participants could execute the desired interactions after very few tries.

The interactions seem to function as an integral part of the excitement for the experience and are perceived very well.

b) Excitement: The installation was characterized as *"fun"*, *"exciting"*, *"a very cool experience"*, and it *"really stays in one's head"*. A suggested usage was as an *"ice breaker"* to improve an event. During the story, the participants showed multiple expressions of delight, ranging from smiles to audible gasps and laughing. During the customer visits, colleagues took pictures and posed with the participants.

The prototype appears to be very exciting and engaging. It can be assumed that the event will create lasting memories and can be an additional thing to talk about after the visit.

c) Cognitive overload: Participants reported that at some points in the experience, they felt overloaded by multiple things being visible and happening simultaneously. This can be movement, text, visuals, and interactions. It was mentioned when *"things overlay each other"*, *"I had to read and listen"*, but also that *"things were happening 360 degrees around [the participant]"*. The subtitles were sporadically mentioned to obscure elements or be distracting. Also, one participant reported the experience may be too calm and more could be happening.

Cognitive overload is an essential factor to consider in creating such experiences. Issues can originate from overlaying stimuli of one sense, like text, colors, and visuals all in one place, or too many different senses stimulated with voice and visuals. Also, spatially surrounding the user with content can be overwhelming. It also depends on how much the participant has experienced Virtual Reality before.

d) Exploring and feeling lost: How they felt in terms of exploring the environment ranged from *"I always know what to do next"*, over *"explorative lost"* to wishing for *"more guidance"*. When colleagues watched, the participants asked for help with what to do next, and comments were made like *"Sorry that I am so slow"* and users seemed to become stressed. To solve this, a more explicit introduction was suggested for specific representations within the experience: "You should directly say, 'this is your company' and 'this is Celonis". This should help to create the favored *explorative-lost* feeling.

Where on the spectrum between *helpless-lost* and *explorative-lost* a user is might depend on different factors. A particular feeling of being *helpless-lost* is when colleagues watch the participants, and they are 'put on the spot'. It was more of an *explorative-lost* if they were alone and could take their time. Also, how experienced they are with games and Virtual Reality games seems to have an impact. Furthermore, the situations of feeling lost seem to happen when the user must understand the story to choose the following action. This might indicate that this little barrier in the flow could help to ensure that the experience is not just seen like a game, where the user tries to find the next thing to activate, but like a quiz that needs to be understood to progress.

e) Individualization: When the test participants working in sales were asked what they would change if they wanted to use it with their customers, individualization was mentioned the most. The requested adaptions were changing the customer logo, source systems, kinds of processes displayed, and showing data of the visiting customer.

Individualization is often used in sales interactions to help the prospect identify with the story. It was also mentioned that it is not required but a nice-to-have extension.

f) Content length and depth: The depth of the explanations was commonly described as the right level, with comments in both directions: that it should go deeper or was already too deep. The most frequently mentioned content expansions were to explain and demonstrate the AI integration more and differentiate CCPM and OCPM more specifically and visually as a product. The average time spent in the experience during user tests was approximately 9 minutes.

Requirements around the explanation depth of OCPM are most likely very closely tied to the audience. More technical or academic users would like to understand on a more fundamental level, whereas business leaders want a compelling story about the business benefits explained in simple terms.

g) Visual: Multiple participants described the experience as visually pleasing. The use of black was mentioned by one participant as *"well-looking but visually heavy"*. The accentuated use of colors was remarked as positive. The pixelated line rendering of a particular animation was perceived negatively by one participant.

This seems to show that the simple, abstract representations and colors positively impact its reception. Overall, the experience is perceived as styled instead of a prototype, with just a few things to improve to reach universally accepted fidelity.

h) Usage suggestions: The participants have suggested multiple additional usages: Academic partner days, the International Conference on Process Mining, guest lectures, executive read-outs, and onboarding of employees and partners.

The experience seems to fit many more use cases, even without altering the current version.

5.5 Encountered Issues

During the evaluation, few technical issues were encountered:

- One user test had to be restarted because a state change was not triggered. This happened after a particularly playful interaction with the objects.
- Three button presses to continue the story were unintentionally aborted. They had to be repeated by the user.
- One time, the internet connection dropped. The user did not immediately realize the issue because the experience skipped over spoken parts, and no error was displayed.

The bugs and interruptions were not problematic for the user tests besides having to restart. They are considered for further improvements.

6 Discussion

This chapter first looks at the general viability of using the experience. Then, the utilization within EBC and other areas within Celonis is discussed, and the next steps are debated. The chapter ends with current limitations and possible experienced biases.

6.1 Assessment of Safety and Usability

During testing, no participant experienced any form of cybersickness. Also, no participant experienced the content as particularly negative or upsetting. The installation should be safe to use with a wide variety of subjects.

At the moment, the implementation is a one-size-fits-all approach. This might lead to situations when the experience does not address the right level of detail. When used with important user groups like prospects and partners, the installation should always be accompanied by a sales executive or partner manager to support the story and answer detailed questions.

6.2 Usage in the Executive Briefing Center

The created experience focuses on the EBC in Munich. The following section discusses the immediate use, recommended setup, and next steps.

6.2.1 Immediate Use of Experience

As the experience received positive overall feedback and support in the immediate use of the current version, it should be used for future customer interactions. The excitement level is an integral part of the experience, and the novelty of Mixed Reality itself supports this; therefore, the experience should be extensively used soon.

The experience can complement the existing EBC agenda by introducing a new, exciting format, activating participants, and creating memorable experiences. It can be something participants of the EBC talk about afterward, which can help spread the word about Celonis as a whole.

As the application has been found to not provide extensive learning by itself, it should still be complemented by other, more educational sessions.

6.2.2 Recommended Setup

The experience takes, on average, nine minutes. It can be a small coffee-break filler or used while waiting for other participants to arrive. A 30-minute session can accommodate three to six participants, depending on whether two headsets are used simultaneously.

During tests with customers, the overall setup has shown to be important for how comfortable users feel during the experience. For any customer visit, it should be carefully evaluated if colleagues should be able to observe through a screencast what the participant does. So far, the screencast has been shown to allow to integrate more visitors at once. A suitable first person to participate should be chosen if colleagues can watch. Some users could feel uncomfortable being put on the spot. If there is enough time to accomondate the experience for all visitors, no screencast should be done.

6.2.3 Increasing Availability

To use the experience more frequently, additional personnel should be trained to set up and configure the experience. There should be handover documents with a step-by-step guide including common issues and frequently asked questions. This will allow to use the app regularly at EBCs if required without needing specific people to be present. Furthermore, the experience should become simpler and more stable to minimize the possible issues.

A few weeks should be invested in implementing solutions to address minor issues. This includes:

- A better internet error handling to ensure the user recognizes the issue. Currently, there is no error displayed, the voice just stops working.
- Reducing the visual overload at specific points of the experience, for example, the moving data-balls at the final screen.
- Improving the usability issues with unintended aborting of button presses.
- Subtitle placement should be chosen by the user at the start of the experience.
- The ability to hide subtitles at the start or during the experience.
- More minor design adjustments like the anti-aliasing issue.

6.2.4 Allowing for Customizability

In the near term, the ability to customize specific elements should be implemented. This includes customer logos, source system names, and process type names. Spoken text, in general, can be interchangeable as this would just be changing the variables in the main model of the view controller architecture. The customizations per customer must be simple enough to be done by non-technical employees to allow the EBC team to operate autonomously.

6.2.5 Using Customer Data

Displaying customer data in the application has been mentioned several times. Implementing this functionality within the Unity prototype would require a data connection to Celonis and a complete design of the interactions a user could take. Once the data is there, the user might want to interact with it, similar to working in Celonis. It would need a real-time connection to Celonis for the displayed data and extensive user-experience research to craft the interactions.

While an interesting topic, implementing this feature would require much time and resources, presumably more than was needed in this study.

6.3 Usage in Additional Areas at Celonis

The interviews showed that there are additional ways that Celonis can make use of the installation. The most promising areas are events and self-service.

As the only specific requirements beyond the standard requirements of the Quest 3 are to have a minimal space of 2.4m x 5m or optimally 3m to 6.5m, the experience can be taken to events or other locations. Those other locations and events could be trade fairs, internal company events, or external company events like the Celosphere [52] and World-Tour [53].

6.3.1 Celonis Academic Alliance

Especially the Celonis Academic Alliance showed a lot of interest. The Process Mining Conference ICPM, student visits, and Academic partner days are possible application areas and events.

Expanding on some parts of the explanation for academic use could be beneficial to make it less business-focused and more academic and technical.

The main parts to improve are being more explicit about the difference between CCPM and OCPM on a structural level, explaining divergence, convergence, and deficiency, and including more visual representations of OCPM. Also, the advantages of using AI and its current implementation should be expanded to create believable and robust arguments. Celonis is considering hiring a working student to implement these changes.

The inventor of process mining, Wil van der Aalst, tested the experience, approved its content, and expressed that he liked it a lot. He now wants to announce an invitation to write a follow-up master's thesis with him and Celonis.

Celonis has a strong partnership with the German Museum in Munich and exhibits technological showcases. The Academic Alliance team has suggested requesting a temporary exhibition and is in the process of contacting the museum.

6.3.2 Allowing for Self-Service

The installation should become self-serviceable for Celonis employees to increase awareness and usage further. Employees could go into the designated area, read a short manual, and use the headset themselves. To ensure users won't get stuck, a hint could be displayed after the user is in the same story state of the application for a longer time. Automatic restarting of the application will also make it easier to use autonomously.

6.4 Limitations and Biases

User group: Although the user group was slightly skewed towards younger and more proficient MR users, the results should be mostly valid. Nevertheless, further research with the specific user-group should be conducted.

User tests: The tests and surveys were conducted by and in the presence of the creator of the experience. This might lead to rating the experience higher because the participants did not want to hurt the feelings of the experience creator. The designer also did the interviews, which might have introduced experimenters and confirmation bias.

There might be a selection bias because more potential participants were invited than ended up accepting. Employees who are more open to Mixed Reality could be more likely to accept the invitation. This was tried to be circumvented as much as possible by inviting only about 20% more people than available slots. Also, the participants were consciously chosen to represent a diverse group.

The user tests might not have represented the real-world experience as they were done without additional spectators. This might be a more relaxing situation.

One limitation of the test is that no follow-up questions were done to test how much the users remember or feel about the experience after some time. Only subjective, immediate answers are available.

Influences of screencast on experience: Screencasting one person's experience to their colleagues seemed to have sometimes introduced stress. Researching and testing different screencast settings and comparing sessions with and without screencasts could be beneficial.

7 Conclusion

This study aimed to create a Mixed Reality experience and test whether it can generate excitement and understanding around Object Centric Process Mining (OCPM), in the context of Executive Briefing Centers (EBC).

Personas and requirements were created based on EBC visitors and Celonis stakeholders to guide the development process. Viability studies were performed with vertical prototypes to define basic concepts and interactions. After deciding on the Meta Quest 3 headset, the final prototype was developed using an iterative approach. Real customer visits to the EBC and extensive tests with Celonis employees and partners provided comprehensive insights.

This study elicited the main business advantages of OCPM. Fun and intuitive interactions and easy-to-understand representations were mapped on these key learnings. They were enforced with overviews, summaries, and learning snippets.

The results show that the installation was perceived as a beneficial experience that should be included in sales interactions. It complements the current EBC offering by creating excitement and memorable situations that might improve its effectiveness.

While the implementation is perceived as educational, it should not be used as a standalone learning experience but accompanied by further informational sessions.

The experience is safe to use as it showed minimal risk for cybersickness and was suitable for a broad range of audiences with very generic explanations and content.

To carry the momentum of the novelty of Mixed Reality and the experience itself, the installation should be rolled out fast within the EBC and at other events.

Parallel to this rollout, the minor improvements suggested in Section 6.2.3 and the ability to customize customer specifics should be implemented. Developing the content further is optional but possibly helpful to expand and adapt it to additional user groups like academics.

Terms and Definitions

Celonis: This thesis has been created with and for the company Celonis. Celonis develops process mining software to improve business processes.

Executive Briefing Center (EBC): Refering to a program or event tailored to a particular prospect company, typically at a specific physical location. Celonis invites high-level decision-makers of prospect companies, usually shortly before a potential upsell, to provide a highly customized, informative sales experience.

Source Systems: These are the systems where data originates. In the context of process mining and business analysis, source systems are the IT systems (like ERP, CRM, etc.) that generate the event logs used for analysis.

Enterprise Resource Systems (ERP): ERP systems are comprehensive software platforms organizations use to manage day-to-day business activities such as accounting, procurement, risk management, and supply chain operations. ERPs integrate various business processes and try to enable data flow between them.

Case Centric Process Mining (CCPM): A traditional way of process mining. Objects within a process are flattened to one case key.

Object Centric Process Mining (OCPM): A new process mining technique. Adding the notion of objects as a new dimension creates a more effective foundation for process mining software.

Data Model: "A data model organizes data elements and standardizes how the data elements relate to one another."[54] In the context of Celonis, it is data organized in a specific process format, including event logs and case tables.

Object: In the context of OCPM, an object represents any tangible or intangible document, item, or thing. Examples are invoices and invoice items, purchase orders, or produced goods.

Mixed Reality (MR): Experiences between entirely virtual or fully real environments on the Reality-Virtuality Continuum. Following the definition of Milgram et al. [24]

Spatial Computing: A term recently re-shaped by Apple to describe a new paradigm of computing where spaciality, the location of objects in a space, is important. [28]

PCVR: Virtual Reality where the headset is connected to a PC. The calculations and rendering are done on the PC, not the headset itself.

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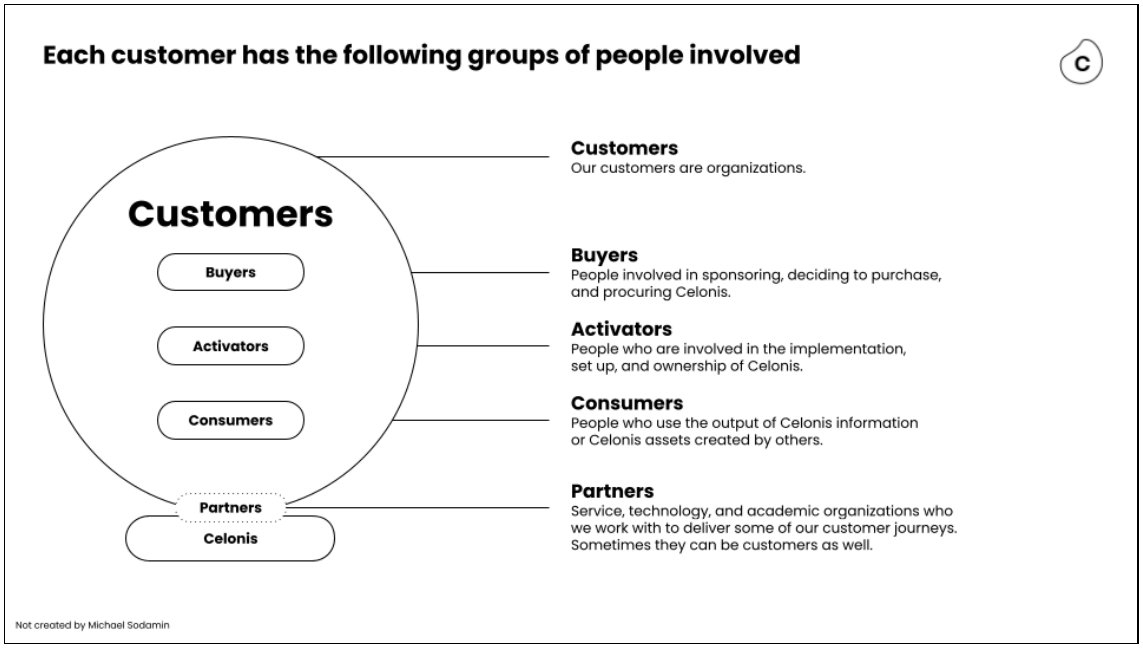
Appendices

Appendix A: Persona Slides



Sieglinde C-Level

Demographics
- 45-55
- White
- US & German

Motivation
- Expansion of Celonis investment after first successes
- Wants quick return on investment as part of their digital transformation journey

Job Title
- Head of (Celonis) CoE
- Chief Information Officer
  - including close below

Information required
- Does Celonis fit for my challenges?
- Does Celonis bring me value?
- How do I set Celonis up in my organization?

Background knowledge
- Basics of Celonis, though mainly the standard process mining
- Some value stories of other customers
- There might have been some challenges of slow adoption and complicated setup from existing Celonis installations

Organizational Goals
- Improve Bottom, Top and Green Line
- Become technology leaders
- Be in control of their operations

Individual Goals
- Build a career on the strategic investment in Celonis

VR Experience
- Used a headset on a trade show once

Constantin Consultant

Demographics
- 25-35
- White
- German

Motivation
- Expand their sales portfolio with OCPM Celonis
- Integrate more consulting projects in Celonis sales

Job Title
- (Senior) Consultant
- Associate Partner

Information required
- In which cases can I integrate it into my offering?
- How is it different from what I do right now?

Background knowledge
- Good knowledge of Celonis
- Just marketing or no knowledge of OCPM

Organizational Goals
- Increase sales of software
- Increase sales of man-days for consulting projects

Individual Goals
- Become the partner company internal Celonis expert

VR Experience
- Used VR headsets before*

*provisional

Appendix B: Requirements List

Requirement ID	Requirement Type	Name	Description	Priority (MoSCoW)	Source	Acceptance Criteria / Measurement
REQ-001	Non-Functional	Color Scheme	The VR experience should predominantly feature black and white colors.	1 - Must-have	Chief Design Officer	The color scheme is confirmed to be primarily black and white. By a design review.
REQ-002	Functional	Change perspective	The VR experience should illustrate how OCPM allows to change perspectives on your data. Taking the perspective of a different object. More than in Case-Centric Process Mining	1 - Must-have	VP Product Marketing	Users can switch between different perspectives within the VR environment. At least 2.
REQ-003	Functional	Faster time to value	The VR experience should show how OCPM offers faster time to value.	1 - Must-have	VP Product Marketing	User testing shows reduced time to achieve specific tasks compared to traditional methods.
REQ-004	Functional	New use-cases	The VR experience should show that OCPM supports use cases that traditional process mining cannot.	1 - Must-have	VP Product Marketing	Identification and successful execution of unique use cases.
REQ-005	Functional	Business Relevance	The content should not be technical but relevant to business executives. The focus is on business advantages, not implementation details.	1 - Must-have	EBC Team	The story should be mainly guided by advantages and does not focus on data visualization etc.
REQ-006	Non-Functional	Large user group	The experience works well for most people.	1 - Must-have	Academic Advisor	From the end user-group, at least 80% should report that the experience worked well for them regarding non-content factors like nausea, orientation, ease of use. The end-user-group should include novice VR users.
REQ-007	Non-Functional	General Applicability	The experience must apply to many different companies and users. It should not require specific data or much information about the customer to make it work.	1 - Must-have	EBC Team	The adjustment time between visiting companies is very low, less than 30 minutes.
REQ-008	Non-Functional	Memorable experience	The experience should be something special to remember.	1 - Must-have	EBC Team	Over 70% of users state the experience as memorable.
REQ-009	Non-Functional	Educate Around OCPM	The Experience should help to understand OCPM better.	1 - Must-have	EBC Team	Users report a subjectively increased understanding of OCPM. OR Users can better fill out a questionnaire about OCPM and its functionality.
REQ-010	Non-Functional	Color blind acceptable	Should be fully usable for colorblind people.	1 - Must-have	Customer Experience	Clear differentiation of colors, check when there is ambiguity. Check with a colorblind person. (on a screen we can use test systems, but not sure if that fully applies to VR headsets).
REQ-011	Non-Functional	Rough duration	The experience should be long enough to teach important aspects (must-have requirements) but not too long to hold back the flow of the EBC.	1 - Must-have	EBC Team	Should be about 6 minutes long, +- 2 minutes. Tested and 80% fulfil this timing.
REQ-012	Non-Functional	Comfortability Rating	Should be comfortable to use and not create feeling of sickness	1 - Must-have	Academic Advisor	If in doubt: Simulator Sickness Questionnaire (SSQ) rating.

REQ-013	Non-Functional	Exit rates	How many people leave the experience either because it is uncomfortable or it is not relevant or interesting for them.	1 - Must-have	Author	Less than 10% exit before the end.
REQ-014	Functional	Show Value	Focus on Value as the main part that this impacts. Together we can create value from processes.	1 - Must-have	Company Pitches	Value must be shown and accepted by the EBC team.
REQ-015	Functional	Interactivity	The VR experience should allow users to interact with the virtual environment. To enhance user engagement and content retention rates.	1 - Must-have	ChatGPT - VR Best Practices	Users can select, move, or manipulate virtual objects.
REQ-016	Non-Functional	Load Time	The VR experience should load within a reasonable time.	1 - Must-have	ChatGPT - VR Best Practices	Load time should not exceed 15 seconds.
REQ-017	Non-Functional	Retro Science Fiction	The VR experience should evoke a sense of retro science fiction.	2 - Should-have	Chief Design Officer	User feedback indicates a retro science fiction vibe.
REQ-018	Functional	Less code and maintenance	The VR experience should show that OCPM requires less code and maintenance. To illustrate the efficiency aspect of OCPM.	2 - Should-have	VP Product Marketing	Codebase is smaller and requires less frequent updates than traditional solutions.
REQ-019	Non-Functional	Maximum Runtime	The experience should have a maximum runtime (e.g., you cannot go back). To allow for a smooth continuation of the visit.	2 - Should-have	EBC Team	The experience should allow for a timely stop. Exact time to be defined, around 8 minutes or through an external impulse.
REQ-020	Non-Functional	Long-lasting impact	The experience should be set up so that it can be used also after the thesis project. It might involve some improvements from an agency but should work in itself already.	2 - Should-have	EBC Team	Experience is used similar like created in thesis, or based on knowledge created in the thesis in June 2024
REQ-021	Non-Functional	Low Maintenance	The experience should require low maintenance by the EBC team to be run.	2 - Should-have	EBC Team	Daily setup time should be below 5 minutes, and per-user setup time should be below 30s.
REQ-022	Non-Functional	Comfortable view area	The view area should rather be a panorama, and not include content above or below to be easier to view (e.g., when standing inside the Process Sphere)	2 - Should-have	Academic Advisor	Primary content should be in front of the user, secondary to the peripheral and almost or no information on top or below the user.
REQ-023	Non-Functional	Limited choices	Limiting the choices of the user to reduce the effort of creating a story for the person.	2 - Should-have	Author	Have around 3 choices for two different things to do.
REQ-024	Functional	Finish with an execution	The end of the educational experience should be that the user “executes” something. Virtual or in real. This is to illustrate that Celonis is not just analytical but meant to help to execute.	2 - Should-have	Author	There is a reference to executing something, or the user executes something in the experience. (e.g., trigger the removal of a payment block etc)
REQ-025	Non-Functional	Outside guidance needed	The experience should be usable without outside guidance.	2 - Should-have	Author	In less than 50% should be an outside intervention needed.
REQ-026	Functional	Abstract OCPM representation	Should have an abstract representation of an OCPM Graph to make understand how it is better than the normal graph. This should also reference to our Marketing material and	2 - Should-have	Author	There should be a similar representation of OCPM like in the marketing material to create a mental bridge.

			bridge the gap to the real product.			
REQ-027	Non-Functional	User Onboarding	The experience should include a brief tutorial or guide. This should be kept to a minimum and just ensure they know what to do. It can be embedded into the story as it progresses and constantly shown as tips.	2 - Should-have	ChatGPT - VR Best Practices	At least 90% of users understand the basic controls after the tutorial.
REQ-028	Functional	Audio Integration	The VR experience should include spatial audio.	2 - Should-have	ChatGPT - VR Best Practices	Audio should be directional and adjust based on user orientation.
REQ-029	Non-Functional	Retro Science Fiction - Small interfaces	The VR experience should include fake interfaces with small numbers running up and down. - Adds to the retro science fiction vibe.	3 - Could-have	Chief Design Officer	Fake interfaces are visibly integrated into the VR experience.
REQ-030	Non-Functional	Video Pass-Through	There should be an option to compare the experience with and without video-passthrough to test for user comfort.	3 - Could-have	Academic Advisor	One user-test done comparing both options.
REQ-031	Non-Functional	Gaze selection	Selecting elements through gazing on them for some time. Selection might be additionally.	3 - Could-have	Author	User can advance the story with just their eye gaze
REQ-032	Non-Functional	Localization	The experience will not support multiple languages.	4 - Will-not-have	ChatGPT - VR Best Practices	It will only support English
REQ-033	Non-Functional	Cross Platform Compatibility	Will not be available on multiple platforms.	4 - Will-not-have	ChatGPT - VR Best Practices	Available most likely on Meta

Appendix C: Headset Evaluation Criteria

Requirement	Reason	Importance
Inside out tracking	Flexibility of use and free movement	high
Support for glasses	Multi-user - for everyone	high
High resolution	Text being used	high
Development SDKs	Should work with Unity and Unreal engine (Support for the features like hand, eye tracking…)	high
Eye tracking	"Magical" interactions, new, could give insights into usage	medium
Hand tracking	Natural, easy to learn interaction, new	medium
IPD adjustments (best automatic)	Easy to set up and use	medium
Video passthrough	Novel, allows for gradual intensity increase and connection to real world + usage in crowded rooms without loss of orientation and safety for others	medium
Vital sensors	Heart rate, skin conductivity etc could be nice to analyze results	low

Table 4: Headset evaluation criteria list

Appendix D: Survey Questions and Results

Consent form

Dear participant,

thank you for participating in this evaluation.

Important:

- You can abort the evaluation process for whatever reason at any stage. All tests will then bestopped immediately. All of your test data will be erased immediately. You do not need toexplain why you want to abort.
- Feel free to remove the headset in the unlikely event that you experience "cyber sickness" (feeling dizzy because of the real vs virtual movement mismatch).
- Let us know if you have any pre-condition like epilepsy or similiar.

You will be using a Mixed Reality Headset (Meta Quest 3) running a custom, in-house built application. It is a prototype for possible experiences as part of the Executive Briefing Center (as well as other audiences). The experience will take about 10 minutes and is self paced. You can ask questions if required but we will try to interfere as litte as possible with your experience.

- I have read and agree to the statements above. (Y/N)
- I confirm having no condition like epilepsy or similar that puts me at special risk. (Y/N)
- I agree to be video-recorded during the session. This recording will be deleted at the end of the study. (Y/N)

Pre-Survey Questions

Question	Scale
Age	Numeric
Sex	male/female/other
Relationship to Celonis	Employee/Customer/Partner
Department	Sales / Value Engineering / Partner Management / Product / Engineering / Other
What describes you best	C-Level / Manager of Managers / People Manager / Individual Contributor
Are you color-blind?	yes / no
Can you see in stereo mode? (You can estimate depth better with both eyes open than with just one)	yes / no / I don't know
When have you last used a Virtual Reality or Mixed Reality Headset?	In the last month / In the last 6 months / In the last year / More than 5 years ago / Never
How familiar are you with Mixed Reality or Virtual Reality headsets?	7 point Likert scale
How comfortable would you be right now with explaining Object Centric Process Mining to a colleague?	7 point Likert scale

Table 5: Pre-survey questions and scales

Post-Survey Questions

Question	Scale
This experience was overall positive for me	7 point Likert scale
I learned something from this experience	7 point Likert scale
In addition to the current state, the experience should be considered to be developed further.	7 point Likert scale
How comfortable would you be after this experience with explaining Object Centric Process Mining to a colleague?	7 point Likert scale
How likely would you be to allocate budget or headcount to investigate Mixed Reality for Celonis.	7 point Likert scale
What is your mother tongue? (to choose INTUI test language)	English, German or Other
I think we can use the experience, as it currently is, to customers, partners, or celonauts.	yes / no

Table 6: Post-survey questions and scales

Survey Results

Question	Mean	Std-Dev
This experience was overall positive for me	6.53	0.52
How likely would you be to allocate budget or headcount to investigate Mixed Reality for Celonis.	5.47	1.46
Age	30.6	6.27
How familiar are you with Mixed Reality or Virtual Reality headsets?	3.47	1.68
In addition to the current state, the experience should be considered to be developed further.	6.13	0.92
I learned something from this experience	4.87	1.85
Pre: How comfortable would you be after this experience with explaining Object Centric Process Mining to a colleague?	4.6	1.64
Post: How comfortable would you be after this experience with explaining Object Centric Process Mining to a colleague?	5	1.41
Difference between UP_1 and UP_2	0.4	1.18

Table 7: Survey results of numeric questions

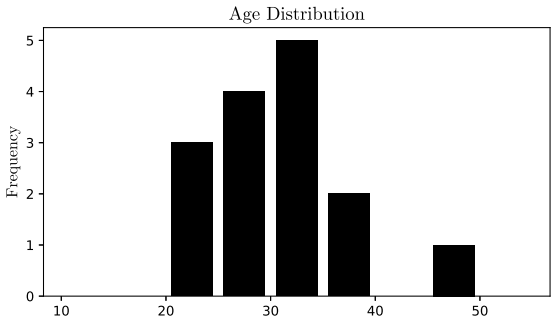
INTUI Detailed Scores

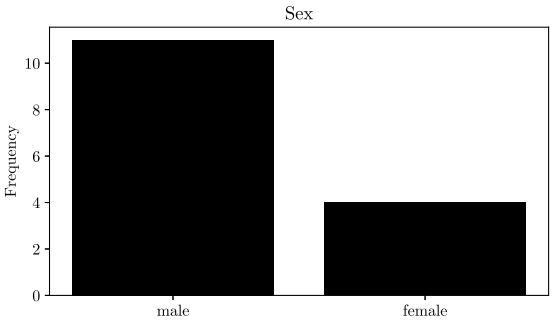
Group	Left	Right	Rev	Mean	Std-Dev
While using the product	…it took me a lot of effort to reach my goal	…I reached my goal effortlessly		4.87	1.3
While using the product	…I felt lost	…I easily knew what to do		5.2	1.37
Using the product	…required my close attention	…ran smoothly		4	1.46
Using the product	…was easy	…was difficult	x	5.27	1.39
Using the product	…came naturally	…was hard	x	5.87	1.13
While using the product	…I acted deliberately	…I acted on impulse		3.93	1.49
While using the product	…I performed unconsciously, without reflecting on the individual steps	…I consciously performed one step after another		4	1.56
While using the product	…I was guided by reason	…I was guided by feelings		3.4	1.24
While using the product	…I acted without thinking	…I was able to explain each individual step	x	3.93	1.75
Using the product	…was very intuitive	…wasn't intuitive at all	x	5.4	0.99
In retrospect	…it is hard for me to describe the individual operating steps	…I have no problem describing the individual operating steps		5.13	1.55
In retrospect	…I can easily recall the operating steps	…it is difficult for me to remember how the product is operated	x	5.67	1.84
In retrospect	…I'm not able to express in which way I used the product	…I can say exactly in which way I used the product		6	1.46
Using the product	…was inspiring	…was insignificant	x	6.2	0.68
Using the product	…was nothing special	…was a magical experience	x	5.73	0.88
Using the product	…was trivial	…carried me away	x	5.47	1.13
Using the product	…was fascinating	…was dull	x	6.13	0.64

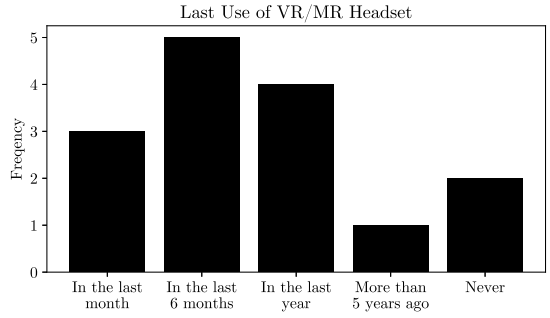
Table 8: Survey results of INTUI test - per question

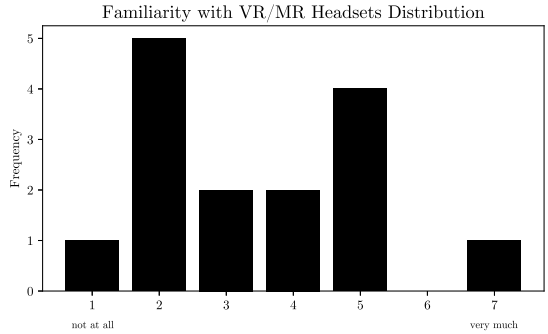
Result Graphs

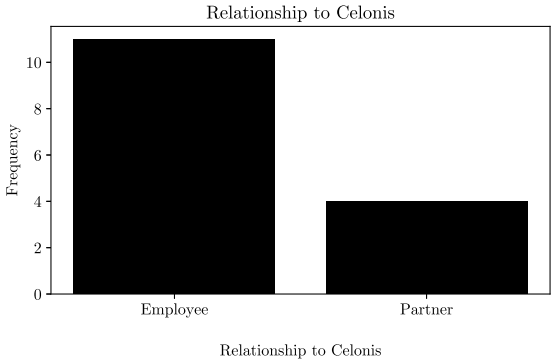
The following graphs only represent the results from the extensive tests; therefore, numbers might differ from the reported numbers in the text, which contain combined data with the customer test.

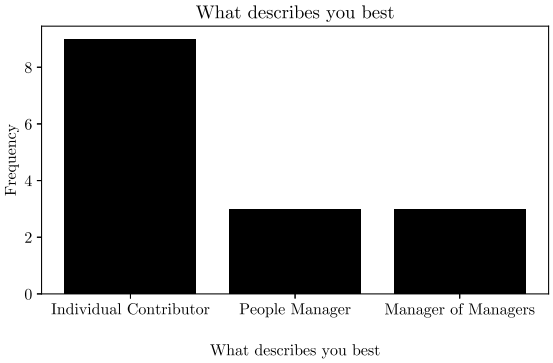




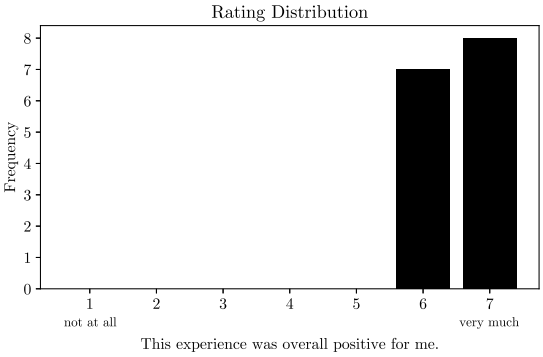


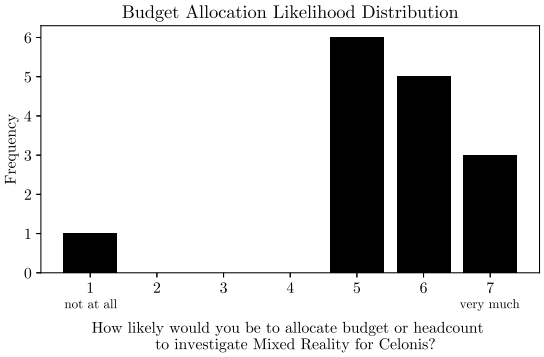


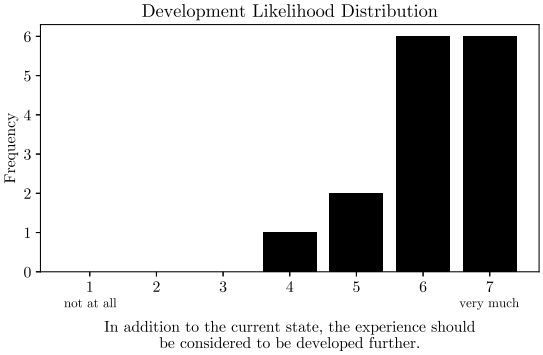


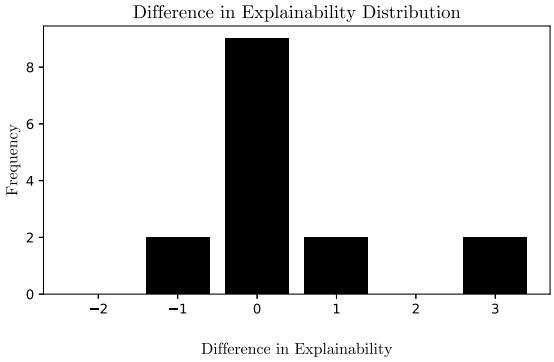


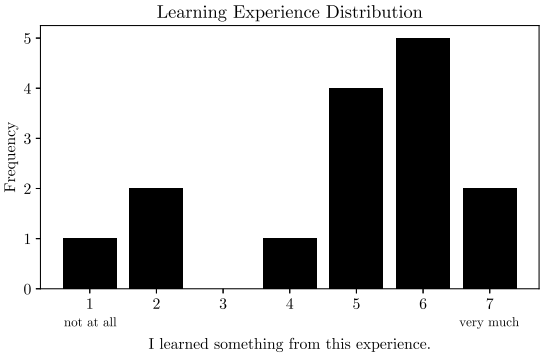

Stereo Vision Distribution
Frequency
Yes
I don't know
No
Can you see in stereo mode?

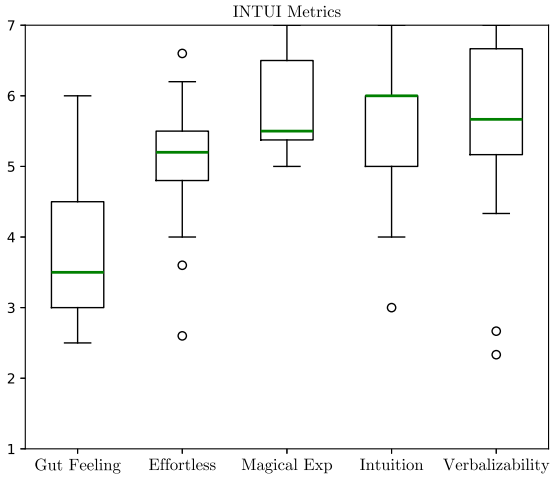

Rating Distribution
Frequency
not at all
very much
This experience was overall positive for me.


Budget Allocation Likelihood Distribution
Frequency
not at all
very much
How likely would you be to allocate budget or headcount
to investigate Mixed Reality for Celonis?


Development Likelihood Distribution
Frequency
not at all
very much
In addition to the current state, the experience should
be considered to be developed further.


Difference in Explainability Distribution
Frequency
Difference in Explainability


Learning Experience Distribution
Frequency
not at all
very much
I learned something from this experience.


INTUI Metrics
Gut Feeling
Effortless
Magical Exp
Intuition
Verbalizability

Appendix E: Experience Trailer and Story Walkthrough

Experience Trailer

Title: Mixed Reality Thesis - Experience Trailer

Link: https://youtu.be/WlE4IQg03Ho (unlisted)

Description: Music from Uppbeat (free for Creators): https://uppbeat.io/t/prigida/catalyst-for-change License code: ZVREFSL4OYV86UWW

Figure 25: Link to experience trailer on Youtube

Experience Walkthrough Demo

Title: Mixed Reality Thesis - Experience Walkthrough Demo

Link: https://youtu.be/FFoyC1AXOIc (unlisted)

Figure 26: Link to experience walkthrough on Youtube

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