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BETWEEN REALITY AND VIRTUALITY. STUDIES ON THE AUTHENTICITY OF REALISTIC DEPICTIONS IN MUSEUM LEARNING

»Museums preserve, interpret and promote the natural and cultural inheritance of humanity«[1]. To this end, museums collect and research natural and man-made objects and other remains. These objects may be works, testimonies of specific events or specimens of a particular species, material or function[2]. They have all generally had a life outside the museum[3]. That makes these objects the »original«, the »authentic« object in the museum sense. The fact that their authenticity is not an absolute characteristic, and that original objects have been changed during their lifetimes, used in different ways or attributed different meanings, has already been observed in many instances[4].

As well as this, there is a series of objects in museum collections that were and are being produced exclusively for the museum itself or its purposes. These include copies, replicas, models or reconstructions. They are used there instead of the so-called original or alongside it and they have a long tradition in the museum[5]. In museum terms, they do not stand for themselves but represent the original[6], and are therefore not authentic by our definition here. Copies and replicas make it possible, for example, to show objects where originals went missing or can only be exhibited with difficulty for conservation or security reasons or are not mobile. They make it possible to show objects for comparison that could otherwise hardly be brought together. Models and reconstructions also make it easier to show ways of functioning, to choose scales suitable for presentation or to show things that are no longer preserved. Life-size replicas of buildings or vehicles, dioramas and scenes enable the visitor to experience three-dimensional worlds that he or she would not otherwise, or at least not in this place, be able to see or experience (**figs 1-2**).

In principle, digital media technologies initially allow similar uses to their analogue prototypes. They also enable three-dimensional representations, from the digital copy to the reconstruction of destroyed objects or past features and structures to the display of complex contexts such as entire scenes[7]. However, media displays offer additional advantages. They can represent any kind of narrative or processes and events – historical, technical or scientific – at a different pace, from slow-motion to time-lapse. They make it possible to change individual parameters of a visualisation or reconstruction and show the changes effected by that and to illustrate them to the visitor or to vary the resolution of the representation. Thereby for example macro- and micro-levels can be transiently portrayed merging into each other, from the microscopic level to the global view. They make it possible to perceive processes in any desired form also with the »x-ray view« and allow the visitor to interact with the objects and manipulate them.

Immersive media, hence media contexts – today mostly using digital Virtual Reality – into which the user can plunge completely, are taking this one step further. Here users can have an immersive experience of space and see artefacts animated and in their original functional context[8]. By the pairing of these impressions with the interaction requirement of immersive media, the once passive viewer becomes the active witness of a complex fabric. »In the immersive context, spectators are automatically challenged to act. Through change in perspective and line of vision, they must actively explore the situation for themselves, which is in strong contrast to a traditional screen projection«[9]. The visitor can choose his own perspectives on what is

In: Dominik Kimmel · Stefan Brüggerhoff (Hrsg.), Museen – Orte des Authentischen? Museums – Places of Authenticity? RGZM – Tagungen 42 (Mainz 2020). DOI: https://doi.org/10.11588/propylaeum.745

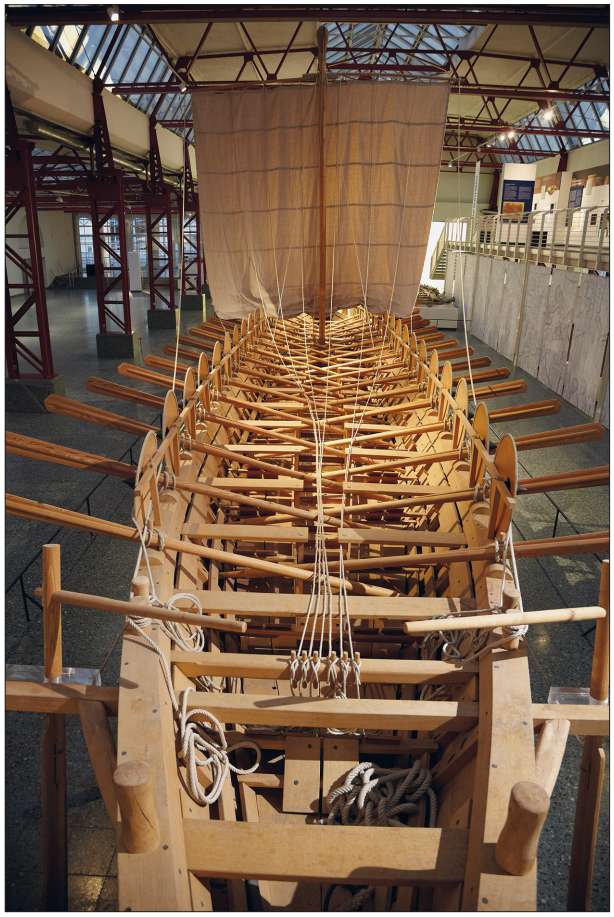

Fig. 1 Replica of a Roman oared vessel from the 4th century after ship wreck from Mainz on the 1:1 scale in the Museum für Antike Schifffahrt of the RGZM in Mainz. – (Photo R. Müller / V. Iserhardt, RGZM).

Fig. 2 Original ship wreckage from Mainz at the salvage in 1981/1982. The wreck formed one of the bases for the replicas in the Museum für Antike Schifffahrt. The wreck is exhibited today in the museum next to the replica. – (Photo R. Wahl, RGZM).

displayed and become active himself. In the most advanced case, he can interact autonomously with the material as a protagonist – e. g. in the reconstructed historical period, or as Shuhei Yoshida, the former president of Sony Interactive Entertainment Worldwide Studios puts it »You can be a witness to some great event, historical, dramatic – it's going to be a powerful medium to bring storytelling to«[10]. Using so-called Augmented Reality or Augmented Virtuality makes it possible to display what is real, such as authentic objects or structures, together with what is reconstructed or assumed[11]. Thereby immediate reality (e. g. architectonic relics or archaeological evidence) is optically fused with additional digital simulations, for example by superimposing the camera image of a smartphone pointed at the artefact by digital amplifications. All these analogue and digital forms of presentations and visualisations must be implemented in a way that is appropriate to museum and research knowledge transfer, comprehensibly, possibly having an emotional effect – but always felt to be »authentic« and credible. How they can be used and how they are perceived in the museum praxis is part of a comprehensive research approach being taken by the authors of this article[12], to which the studies and projects described here form a contribution.

In the centre of the authors' common interest stand possible uses and the functioning of material and digital realistic representations, in particular new digital media technologies, in museum knowledge transfer. However, the projects thereby consider constantly the key role of the »authentic« object described at the outset for research and the museum. Our common goal is to gain new experiences and insights for the best possi-

ble transfer of knowledge in the museum by means of public-orientated projects and empirical studies. This article sheds light – very briefly – on a selection of key challenges and questions that we have addressed in various projects and studies, in particular at the Römisch-Germanische Zentralmuseum in Mainz, partly also in collaboration with other research museums, between 2011 and 2019[13].

Fig. 3 Construction of the 360° Rotunda in the Museum für Antike Schifffahrt, 2012. – (Photo M. Orthwein).

EXPERIMENTAL ZONE IN THE MUSEUM – TESTING THREE-DIMENSIONAL REPRESENTATIONS IN DIGITAL AND IMMERSIVE MEDIA IN THE MUSEUM

Fig. 4 Mixed Reality Open Lab (2018). Interdisciplinary discourse between archaeologists, boat-builders, programmers and designers. Peter Werther (boat builder the RGZM), Ronald Bockius (head of the former Forschungsbereich Antike Schifffahrt at the RGZM), Aaron Franz (graduate at Hochschule Mainz, Beyond the Screen), Ferdinand Lotz (technical project coordinator) (from left to right) in the modelling of the 3D reconstruction. – (Photo D. Kimmel).

Since 2011 the Römisch-Germanisches Zentralmuseum, Leibniz-Forschungsinstitut für Archäologie (RGZM), in collaboration with the study programme »Zeitbasierte Medien« (»Beyond the Screen« consecutive course series) at the Hochschule Mainz at the Museum für Antike Schifffahrt (Museum of Ancient Seafaring) has been trialling the use of immersive media as well as various approaches to Virtual Reality in the context of several experimental projects in the current museum operation[14]. Since 2015/2016 the Leibniz-Institut für Wissensmedien has been a partner in the studies.

In 2011, a 360° Stereo Surround Projection Unit (»Rotunda«) was developed for implementing immersive projects in the museum and for the use with students. From 2012 to 2015 this was in operation in the RGZM's Museum für Antike Schifffahrt for the experimental development of various scenes and the technical testing of the Projection Unit itself (**fig. 3**). A broader investigation of the use of new media, in particular Virtual and Augmented Reality, in connection with questions of authenticity has been taking place since 2017 in the Mixed Reality Open Lab (MROL) project in the context of the collaboration. To investigate the possibilities and effects of the use of media, an experimental domain was again created amid the day-to-day museum operation in the Museum für Antike Schifffahrt. In the MROL, archaeologists, psychologists, learning experts, designers and programmers are trialling together how digital reconstructions and future technologies such as Virtual and Augmented Reality can be appropriately used in the museum transmission[15]. An additional partner is the company Tuomi, in Trier. The MROL project was made possible by the Action Plan of the Leibniz Research Museums funded by the federal government and German states for strengthening these institutions as sites of dialogue and knowledge transfer (**fig. 4**).

From 2011 to 2019, the use of wide range of media technologies could therefore be tested: in addition to the 360° Surround Projection Unit (»Rotunda«) various Virtual Reality head sets (Oculus Rift, HTC Vive)

as well as various technologies for generating Augmented Reality (Tablet, Microsoft Hololens). Since 2018 smartphones and tablets with an NFC (Near Field Communication) interface have also been incorporated as a supplementary information interface.
For the various media technologies, eleven digital applications and visualisation projects have so far been implemented. Because of the location of the experimentation site in the Museum für Antike Schifffahrt of the RGZM almost all are thematically based on aspects of seafaring in historical time[16]. In each of these projects, specific conceptual, technical and design challenges could be tested, some of which are described in the next chapter. As the projects were implemented over an eight-year period, they also allow to observe the development of the technical possibilities over time. A platform-independent virtual exhibition of these projects can be seen and visited in an interactive online community experience on the social VR-platform »Beyond the Screen« (www.beyondthescreen.de).

Conceptual and design challenges using the example of experimental productions

Displaying three-dimensional illustrations of objects using two-dimensional media: »criminal archaeology« exhibition in the public space (touchscreen, 2011)

As an element of the city-wide »Zeit.Fenster« exhibition in Mainz on »criminal archaeology« at the Mainz Hauptbahnhof, archaeological objects originating from Iraq were illustrated three-dimensionally on an interactive touchscreen[17]. These were digitally captured using scanning procedures and prepared so that visitors could view the object through the touchscreen by an interaction from all sides. Special technical challenges here were the reconstruction of reflective object-surfaces, as well as the generation of a robust application that functioned intuitively and flawlessly in continuous operation in the public space.

Contextualising and operationalising »reconstructed objects«: Pliny and the Roman fleet at the eruption of Vesuvius (360° 3D Surround Projection – »Rotunda«, 2012)

The first project for the 360° (»Rotunda«) Projection is a short film sequence showing ships from the Roman fleet stationed in Misenum on the journey towards Pompei. Pliny the Elder, the fleet commander, is standing on board a Roman war ship and observing Vesuvius erupting. In 79 AD Pliny mobilised his ships to send help quickly to the inhabitants of Pompeii during the eruption of the volcano (**fig. 5**)[18].
Alongside the various types of Roman ships that are exhibited as models in the Museum für Antike Schifffahrt, this 3D film also showed their historical context – the deployment in the Mediterranean Sea and the reconstructed coast of the Bay of Naples with the erupting Vesuvius. The scene is supposed to transport the visitor into what is an unfamiliar viewing scene for him, putting him in the mood for the later museum experience and making him more receptive to it. To this end, the film features an episode that may be known to the visitor at least in principle and to which he is supposedly emotionally receptive: the eruption of Vesuvius and a rescue operation at sea. Through the background history (context) a strong empathy-factor was created, an emotional reference-point to something that the visitor knows, something that he may find moving.
The film reconstructs what the visitor cannot see from the objects and models in the museum: the ships in operation. It seeks to draw the visitor into the middle of the events in antiquity – as it were to make him or her experience a leap in time, the visitor is supposed to imagine himself completely in the past. The reflection of what is being seen – especially on questions arising about the authenticity – is then to happen afterwards, for instance by viewing the wooden model and reading further information in the museum. The references for the digital reconstructions could be directly viewed in the museum in the area around

Fig. 5 **1-2** Pliny the Elder and the Roman fleet at the eruption of Vesuvius. Still from the 360°-3D projection in the Rotunda in the Museum für Antike Schifffahrt, 2012. – (Photos M. Orthwein).

Fig. 6 **1-2** Movements of people: Naumachia display in the Rotunda. Still from the 360° 3D projection, 2013. – (Photos M. Orthwein).

the Rotunda: wooden models on the 1:10 scale that served as a basis for the digital ship reconstructions. As there are no original primary sources for these types of ship on display in the museum, in the context of the experimental set-up secondary sources (or their photos) that were used among other things as a basis for the ship models were also shown: ships represented on a relief and a piece of graffiti. Visitors could thus draw their own conclusions about the plausibility of the digital reconstruction. In the 360° film, the ships travel an actual route in the Bay of Naples ascertained from geo-data. Many visitors were struck there by the »slow speed of the ships«.

The representation of human movement sequences: Naumachia in the Colosseum (360° 3D Projection, 2013)

In the second project for the Rotunda, a Naumachia, a re-staged sea battle, was visualised. As the Naumachia takes place in a round internal space, the Colosseum, this theme appeared especially well suited to implementation in a 360° projection. As well as the visualisation of details of the pieces of equipment, here in particular the representation of human movement sequences was trialled, in this case in the battle for which only indirect sources are preserved. Concerning the effect of battle wounds in the movement sequence, a forensic pathologist was brought in[19]. The stereoscopic representation of several tens of thousands of spectators became a special technical challenge that stretches the boundaries of the feasibility for such a project in the museum (**fig. 6**).

Fig. 7 Fossa Carolina – proposal for reconstruction: still from a stereoscopic 360° visualisation of the canal by students at the Hochschule Mainz, 2014/2015. – (Rendering M. Orthwein).

Connecting real and digital representations and incorporating modellings: the Fossa Carolina (display for a 360° 3D projection and a two-dimensional presentation medium, 2016)

The significance of this visualisation lies in the fundamental conception of the exhibition of which it formed part: this reported directly from a current research project on the investigation of the Fossa Carolina, Charlemagne's canal for linking the water way systems of the Rhine and the Danube[20]. The sources used here were the survey and excavation findings of the still active scientific project team. The special design feature of this project was the joint use of real and digital film sequences. The technical challenge for that time consisted in processing particularly large quantities of data in the rendering (**fig. 7**).
In the digital reconstruction of the water flow, simple modellings were used in addition to the scientists' findings and considerations. Here in a flow-simulation the media designers visualised the flow action, speed and water volume in the Fossa Carolina. This was also supposed – from a kind of external view of the media designers – to serve the scientists as a stimulus for deepening the modellings and thus for the verifying of the current reconstruction concept. So this digital reconstruction not only fulfils the goal of preparing the reconstruction perceptions for the public, but can also make a contribution to the research on how the canal operated. However, these simple simulations cannot replace tests with models in real water or other more elaborate experimental archaeological approaches.

Making the evidence and reconstruction experienceable: the Madrague de Giens wreck (Virtual Reality as component of an exhibition scenario; Mixed Reality Open Lab project, 2017-2019)

The starting-point of this experimental exhibition scenario in the Museum für Antike Schifffahrt was supposed to be a well-documented archaeological discovery, illustrating both: economic-archaeological aspects

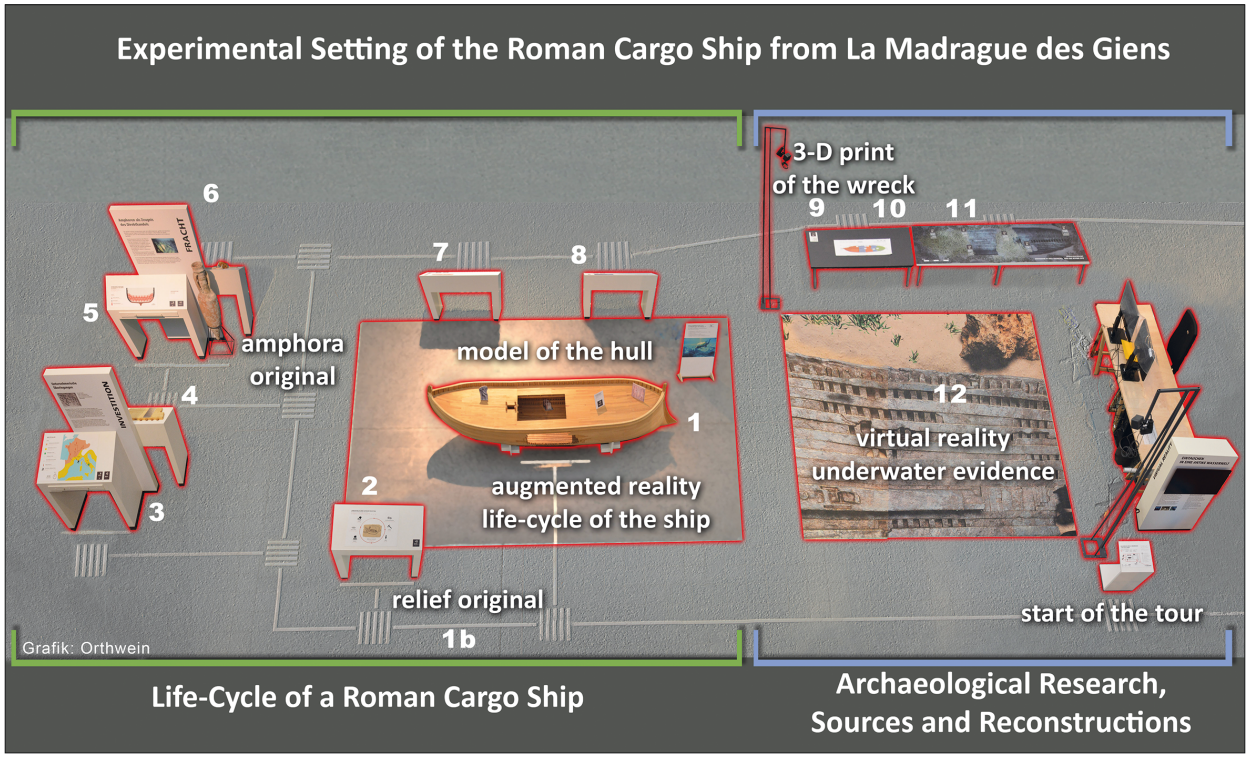

Fig. 8 Mixed Reality Open Lab (MROL) – experimental exhibition setting »La Madrague de Giens« in the Museum für Antike Schifffahrt, 2018/2019. A wooden model of the hull of the cargo ship on the scale of 1:10 stands in the centre of the setting. In a Mixed Reality Application, scenes from the life of the cargo ship are displayed, the archaeological evidence can be seen in a Virtual Reality App. Blind people can touch the entire discovery in 3D printing as well as construction details and selected original artefacts. – (Graphic M. Orthwein).

and methods of archaeological research, in this case in particular the significance of the reconstruction. The choice fell on the so-called Madrague de Giens wreck, a Roman cargo ship that sank in the 1st century BC off the French Mediterranean coast[21]. A wooden model of the hull produced in 2003 in the Museum's in-house workshop on the 1:10 scale is on display in the exhibition. For the communication of the story in the museum, two intersecting narratives were developed using various media (**figs 8-9**).

The first narrative is concerned with the wreck itself, its construction and its investigation. On a first learning level, the VR scenario allows visitors to experience something that would otherwise be impossible for them: they can visit the archaeological discovery, that in reality lies inaccessible under the water. On a second learning level, they gain the possibility of learning how to interpret the archaeological evidence. Derived from this, they are supposed to develop an understanding of the ship's appearance, size and construction and also – in a rudimentary way – its function. This forms the base for a third, overarching – more abstract – goal setting for transmission: by using the application and the accompanying information, the visitor should develop a general understanding of the connection between sources, such as the archaeological evidence like features, artefacts or biofacts, and reconstructions as well as the processes and questions associated with it.

To this end, visitors are led into a virtual underwater world and directly to the wreck. In a virtual dive, experienced through Virtual Reality head-mounted displays, the visitors inspect the wreckage themselves and learn how the underwater archaeologists have left it. The user can move around in a truly accessible area of 5 m × 5 m. To encourage the users to explore, virtual archaeological drawing boards were placed in the wreck set. They transmit additional information about specific features where the user is standing. If a draw-

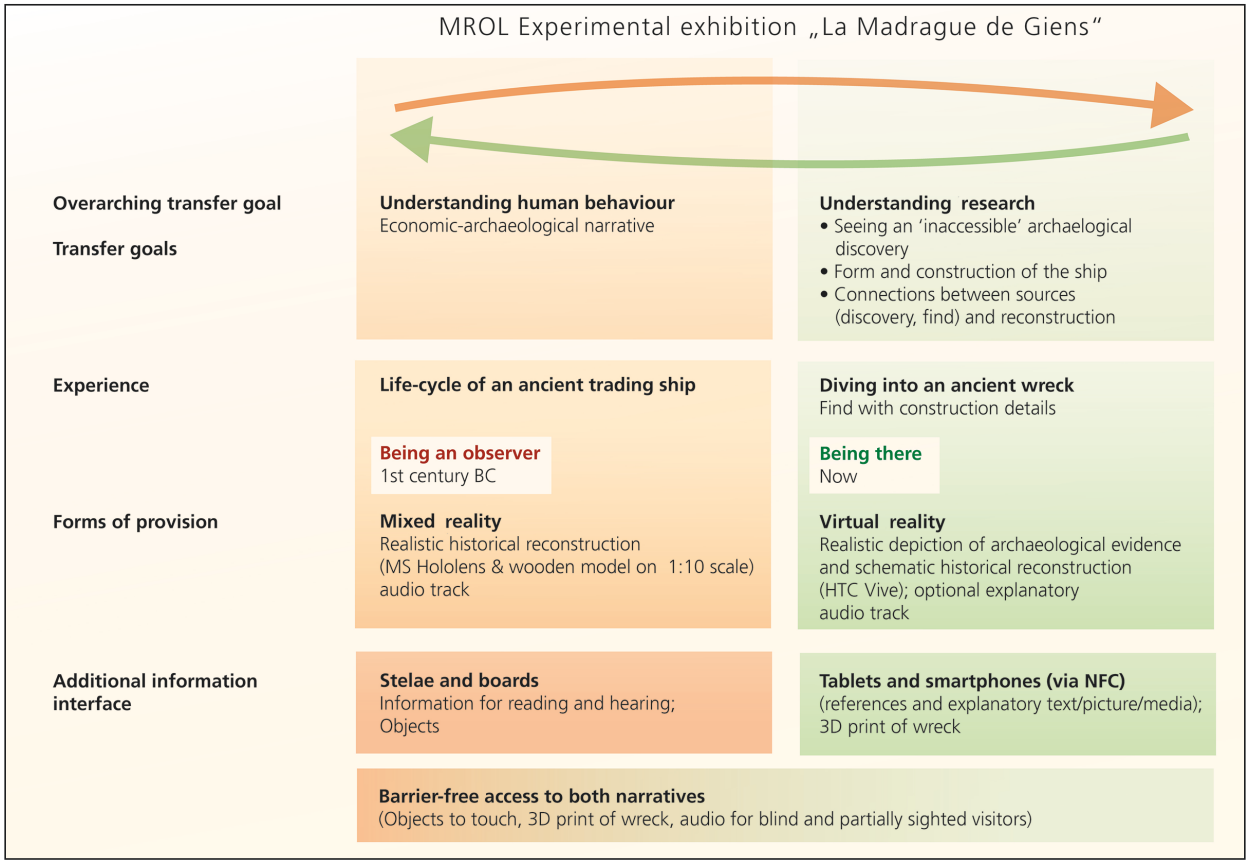

Fig. 9 Mixed Reality Open Lab, 2018/2019: learning objectives and media used in the experimental set-up »La Madrague de Giens«. – (Graphic D. Kimmel).

ing board is picked up by the user, the counterpart to the conceptual sketches presented on the drawing boards appears in the virtual space as a wire frame and in life-size (**figs 10. 17-18**).
Thanks to the extensive documentation of the archaeological evidence, and along with various plan drawings, over 1000 photos could be analysed during the construction of the realistic depiction of the wreck. They provided important information about the arrangement of the finds, possibilities of partial photogrammetry-reference and information about the quality of the surfaces (**fig. 11**). The vast scales and the high level of details of the wreckage set represent a special challenge for the hardware.

Making narratives comprehensible – connecting the real object and the digital reconstruction: the life-cycle of the Madrague de Giens wreck (Augmented Reality in the context of the MROL setting, 2017-2019)

The second narrative in the above-described setting is concerned with economic-archaeological aspects that can be shown using the ship’s reconstruction. In the centre is the life-cycle of the ancient cargo ship, from the investment decision to the accident. For this theme an Augmented Reality Application was created that generates a link between the wooden model and the digital images. If the visitor views the model by using a tablet held in front of it or a mobile phone, he sees reconstructed extensions of the ship, as well as various scenes from its history that are placed above the model. The visitor deliberately does not become part of the action. But he becomes the observer and explorer from a perspective that he can choose.

Fig. 10 Mixed Reality Open Lab, 2018: discovery situation under water with the excavated wreckage and countless amphoras. Different stages of the excavation can be seen. Originally the complete shipwreck was covered with anphoras. Also in the image two archaeological drawing boards that point out special details to the visitor. – (Still from the VR application: Beyond the Screen / Hochschule Mainz, F. Lotz, RGZM).

In the four stages of the life cycle that were visualized – »investment decision«, »construction«, »loading in the port« and »journey« – two presentation strategies are used. In the »investment decision«, a »portal« appears behind the model that shows a life-size atrium of a Roman villa. Here the ship owner and the merchant are negotiating the investment. The real wooden model of the ship on display in the museum here serves as a model in the virtual set. In the second strategy, the wooden model is superimposed by an ideal-representation of the ship. This opens to the viewer the possibility of a »Gulliver-perspective« on an animated 6 m × 7 m digital quasi-diorama. Here the action both in the port and on the ship can be observed (**fig. 12**). Thereby the viewer can determine how close to hold the tablet to the individual figures and objects. In both the Virtual and in the Augmented Reality application, the user himself determines the retention time and the direction of the view, as well as the viewing perspective.

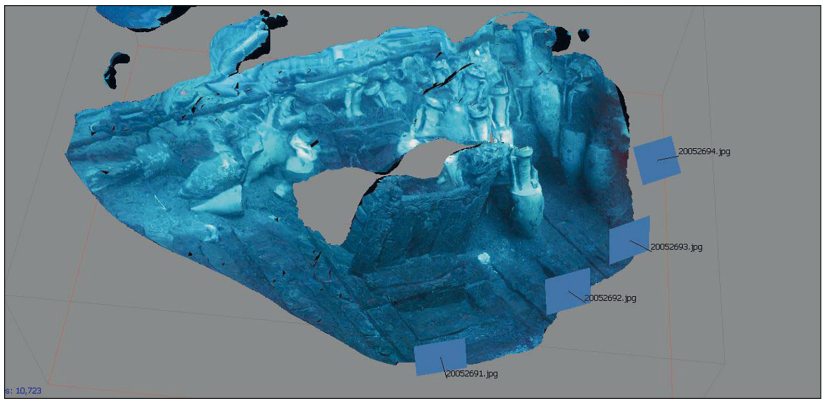

Fig. 11 Mixed Reality Open Lab, 2018: Producing a realistic depiction of the archaeological evidence: the digital reconstruction of the wreck of La Madrague is done from geometries and countless underwater images as references. The picture shows the pump in the middle region of the wreck. – (Illustration Beyond the Screen / Hochschule Mainz).

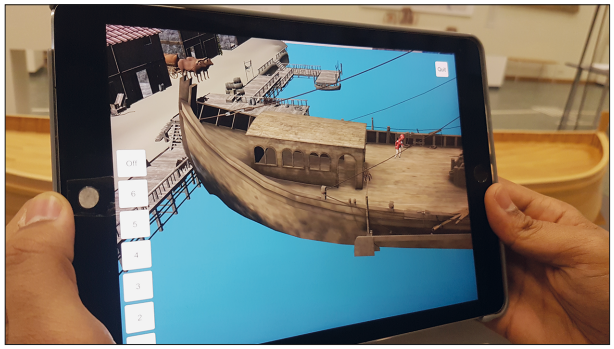

Fig. 12 Mixed Reality Open Lab, 2019: Scene in the port. Augmented Reality Application with scenes from the life-cycle of the cargo ship. Animated images on the tablet amplify the wooden model. – (Graphic Beyond the Screen / Hochschule Mainz; photo D. Kimmel).

Fig. 13 Mixed Reality Open Lab, 2018/2019: Virtual underwater world: visitors using the VR specs (HTC Vive) can move around freely on a surface of approximately five square metres in the space. On the floor is a print of the digital reconstruction of the wreck on the scale 1:1. – (Photo R. Müller, RGZM).

Interaction between the user and virtual technology, movement in the virtual space, Mixed Reality Open Lab, 2017-2019

The rapidly developing possibilities for using Virtual Reality include ever more varied possibilities of the user's interaction with the medium[22]. The VR-underwater world of the Madrague de Giens wreck already contains a series of interactive elements. In his virtual experience, the user is offered not only the opportunity to grasp the vast dimensions of the wreck (around 40 m long) but also in a varied – albeit still modest – way to become active himself (**fig. 13**). The first possibility is moving around in the space. The possibility of teleportation – the virtual leap – allows the user to explore the whole set despite the real space limitation of 5 m × 5 m. This is willingly taken up by users; the study participants use this function on average 12 times per »dive«, which on average lasted 7:23 minutes (at least once, max. 33 times)[23].

Furthermore, with his hand, which is represented by a gripper attached to it, the user can trigger various actions in his virtual world: he can pick up the drawing boards with information distributed in the virtual scene, he can press an audio button and he can pick up selected amphorae, observe them in detail from close-up, move them and stack them – or do with them whatever else he likes (**fig. 14**). With all the interactive objects there the viscosity of the environment (so of the water) is taken into account and simulated. For example, thrown or released objects do not merely fall to the ground but sink down. Without this having been specially instructed, amphora stacking – or even amphora throwing – is developing into one of the favourite activities of younger visitors. The application makes use here of the public's enjoyment of play and, without at this point going further into the content, stimulates it to engage with one of its key messages – the use of transport vessels and the safe storage of cargo. Here many further – also playful – developments of interactions are conceivable. What would be highly promising for example is the possibility of making virtually an »authentic« amphora stacking. Also empirical studies show that many visitors, especially regular VR users, would like more interactions. Interactions also seem to be an essential component in evaluating the level of satisfaction of this visitor group's expectations of the application[24].

Interaction between user, virtual technology and the real, haptically feelable museum object (Remigatio: Bachelor Thesis Project Aaron Franz / Mixed Reality Open Lab, 2019)

A further experimental set-up in the context of the MROL goes one step further. In a Bachelor thesis at the Hochschule Mainz an experiment was conducted with the interaction between the museum visitor and Virtual Reality in connection with the real museum object[25]. For this a VR-application was developed with appropriate hardware construction. The goal of the project was to find and test an approach to a solution for integrating haptics into the virtual application (Augmented Virtuality). Whereas in the Madrague de Giens wreck haptic elements and real museum objects were not yet part of the application, this connection is now the key component of an experimental arrangement around the replica of an oar segment of one of the Roman sailing vessels exhibited in the museum. Here the visitor sits like a Roman rower on the actual replica of a bank of oars and makes authentic rowing movements with the recreated oars. All the movements of the real oar are captured in real time by tracking sensors and transferred to the virtual oar. Through the VR headset (HTC Vive), he sees his movements synchronically, his environment on the ship with further virtually occupied rowing stations and the bank of the Rhine going past him. Unlike in the Madrague wreck application, here a historical scene was made experienceable in Virtual Reality realistically and not schematically (**figs 15-16**).

To make the haptics possible, the oar section already designed and built in 2010 in the Ancient Seafaring research domain of the RGZM was integrated into the VR application. In particular through weights on the oar, a relatively realistic feeling could be transmitted of the force that had to be applied when rowing such a ship. Because of the high security requirements in the museum however the chosen solution is not yet suitable for continuous running in the public operation.

Fig. 14 Mixed Reality Open Lab, 2018: Virtual find situation under water. Amphoras with wine formed the main load of the cargo ship. Visitors can also pick up amphoras virtually. – (Still from the VR application: Beyond the Screen / Hochschule Mainz, F. Lotz, RGZM).

Fig. 15 Interaction between real and virtual world: the connection of the replica of an oar section with the virtual ship allows a true-to-life impression of the oar action. Weights on the oar simulate the felt resistance of the water. Remigatio Project in the context of a Bachelor thesis at the Hochschule Mainz, 2019. – (Photo A. Franz).

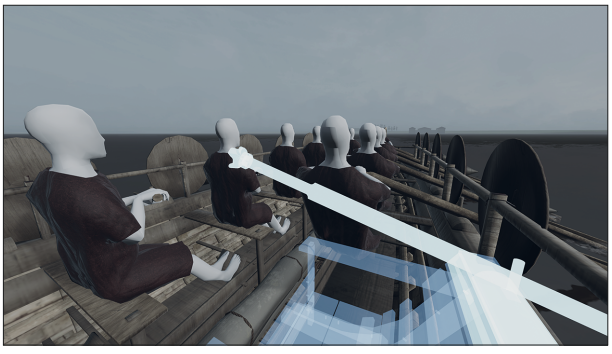

Fig. 16 Interaction between real and virtual world: for the interaction the real world was integrated into the virtual world. Remigatio Project in the context of a Bachelor thesis at the Hochschule Mainz, 2019. – (Photo A. Franz).

OBJECTS, RECONSTRUCTIONS AND DIGITAL MEDIA – EMPIRICAL STUDIES OF THE VISITOR-RELATED EFFECT

For the past few years, new applications for use with digital immersive media have been emerging in increasing numbers in the most various museums. The suitability of the hardware and the applications for the museum operation has thereby rarely been tested or matured because of the rapid further development of the technologies. In the first instance the projects described here contribute to the gain in experiences with the functionality of the medium used and with the implementation of the visual representations. In all projects, we want to find out whether the didactical design as well as the media implementation is accepted by the public, whether it is practicable and works and what kind of effect it has. All the applications so far implemented are therefore designed for use in an experimental museum setting. As described at the outset, the individual projects here serve the evaluation of new media and the technology used as well as addressing further research questions in equal measure. The first visitor-related empirical studies in the Rotunda were carried out in 2014 in the context of a Bachelor thesis[26], and then in 2015 in an observational study concerning the acceptance of partial and total immersion in the context of a Master's thesis[27]. In the context of a survey at the Mainz museum night, the study compared among other things the acceptance of the 360° Rotunda with the Okulus Rift VR head set. To the question »Did you feel transported into another world?«, the users of the head sets answered with evidently stronger agreement than the visitors of the 360° Rotunda[28].

In our projects and studies, we are also concerned with fundamental questions about the understanding of science and humanities and the understanding of research. Much of this has to do with authenticity and so-called authentication processes in the museum. We scrutinise the engagement with the »original« objects and copies, but in particular also with reconstructions. We investigate how »close to reality« the depictions are, their credibility, the value of the sources and how visitors deal with hypothetical or fragile knowledge in reconstructions.

We want to ascertain for example whether visitors understand that reconstructions and models, whether analogue or digital, emerge from comprehensible scientific methods and sources as well as validated hypotheses and how this is best conveyed. We want to find out whether visitors understand that these hypotheses are often also based on fragile or conflicting evidence and how we best deal with this in the museum. Scientifically based answers to this can only be found by public-related empirical impact studies.

In the past few years, visitor research has gone through a multiplicity of theoretical and methodical developments. By now a series of empirical studies has addressed the comparison of original exhibits with their analogue and digital copies and reconstructions[29]. Building on these results, empirical studies were also carried out or will soon be concluded at the RGZM.

A first visitor study at the RGZM in 2015, designed as an interview study and observation with systematic variation in six experimental groups, explored the effect of the original object and the copy with regard to the different levels of meaning of the object for the museum mentioned at the outset[30]. It revealed that visitors clearly distinguish whether an authentic object is an individual work, a historically important testimony or the specimen of a frequently encountered object. A further interview study in 2015 designed as a pre-test at the RGZM's Museum für Antike Schifffahrt, in which the authors accompanied a team of students from the Hochschule Mainz, compared the effect and credibility of three-dimensional digital reconstructions of Roman war ships in the 360° Rotunda with the effect of the traditional wooden models[31]. Furthermore, initial methodical approaches were trialled for investigating the scientist's role in producing reconstructions.

A more comprehensive study conducted in 2017-2018 within the framework of the action plan for research museums also addresses the credibility and the visitor's understanding of reconstructions and the scientific processes that are at their basis[32]. It investigates whether it is better in terms of knowledge transfer in the museum to show the visitor the source first, in this case the original parts of the wreck, and then the (material-three-dimensional) reconstruction or in the reverse order. The results indicate that visitors spend longer with a material reconstruction and find it more credible if they have first inspected the original parts. Another study in the Mixed Reality Open Lab examined a series of questions on the functionality and effect of the above-described virtual underwater world of the Madrague de Giens wreck to be experienced with the VR glasses[33]. The study design which included a survey with observation comprised two intervention groups with 72 subjects in total. One group used the above-described VR scenario without any other museum context; the other received the VR installation in connection with accompanying information accessible through tablets and smartphones. Building on the results of the preceding studies a further interview study is planned with similar sets of questions at the Museum für Antike Schifffahrt in Mainz and the Deutsche Schifffahrtsmuseum in Bremerhaven. This is to examine among other things whether the visitor is engaging with the scientific processes, often based on hypotheses, that underlie these reconstructions and whether three-dimensional digital displays such as Virtual Reality are appropriate for stimulating the understanding of these scientific processes[34].
The results of the individual studies are to be presented in separate publications and therefore only short extracts are presented in this article. Experimental exhibition settings and empirical studies fundamentally serve to develop and test the best possible usage possibilities for museum practice. These settings make it possible to connect the evaluation of specific knowledge transfer formats with more detailed research questions, such as in the context of the research activities of the Leibniz Research Alliance Historical Authenticity.

FUNDAMENTAL CHALLENGES AT THE INTERFACE BETWEEN RESEARCH AND PUBLIC: CONCLUSIONS ARISING FROM THE PROJECTS

The power of three-dimensional realistic depictions and dealing with hypothesis and fragile knowledge

The rapidly advancing developments of digital technologies make it possible in an ever more flawless and varied way to produce three-dimensional objects, reconstructions and models virtually and use them in museum transmission. Modern digital reconstructions allow past things to re-emerge true-to-life in the highest resolution. Immersive media take this one step further. They take the visitor into three-dimensional worlds that he cannot seek out in reality or that no longer exist. He can do virtual »time travel« or transport himself to faraway places. It thereby becomes increasingly difficult to differentiate between reality and virtuality. Therefore museums have a great responsibility, especially in the use of high-resolution digital media. For highly realistic representations or immersive worlds – like life-size replicas or stagings in the space – can leave strong impressions on the visitor. This is both a blessing and a curse. One the one hand, the possibilities continue to improve for creating realistic depictions of things and scenes that no longer exist or that the visitor could otherwise never see. On the other hand, images can become too strong, too suggestive, in their power to convince. It is for this reason that for the reconstruction of past or incomplete material, like historical or archaeological evidence, technical possibilities should not be unreflectingly exploited. The visitor runs the risk of creating for himself an image of the past that probably never existed in that way. Also

more recent insights from research can again lead to a changed image. As a high expertise and seriousness is attributed to the museum as an institution, it is to be expected that the digital representations and reconstructions there are also generally accorded a high credibility by the public. In the experimental projects, we therefore examine how credibly and authentically the various forms of representations are perceived by the public.

The representations should not only be rated as authentic by the user; they should also show what science does not know, where the state of research ends and the discussion begins. In any reconstruction and its visualisation, whether digital, drawn or constructed, we should therefore always ask and make transparent:

- how great is the hypothetical or »speculative« component of the reconstruction and how we make that clear;
- how authentic or verified are the sources and what authenticity should we ascribe to them;
- what status of authenticity we want to convey to the visitor and so also which moment of the object's biography;
- how far we want to let the viewer perceive the gaps in our knowledge and »theories«;
- how important an emotional impact on the visitor is to us.

Visitors' viewing habits generally require that digital images and reconstructions of the past also in the museum are prepared as faithfully to detail and realistically as possible. The more detailed, immersive and interactive they are, the more they will stimulate emotions in the user and the more visitors they will draw into the museum. If at the same time we want to reveal our sources, research processes and gaps in knowledge, some emotional experience will probably be lost. Whether and how this balancing act can succeed is a component of the trials and investigations described.

Engaging with the sources

Credibility and plausibility through the comprehensibility of the scientific processes

Models and reconstructions, whether analogue or digital, allow us to show what cannot otherwise be seen. In the museum and in knowledge transfer, they are generally the result of scientific discoveries. If these scientific insights and their results are to be transmitted as intrinsically validated and credibly, and not only extrinsically through the credibility of the transmitting institution or scientists, all the processes of scientific method, through the documentation to the transmission in the museum, must be plausible and credible. Ideally to this end all processes between evidence, reconstruction and further interpretation are made transparent and comprehensible[35].

»Authentic« objects in the museum play a key role in this. Together with detailed documentation of the contexts and discoveries from which they originate, they convey information or constitute sources for the scientific discovery processes. They are the evidence for our scientific statements and further interpretations. Digital media can help in making these processes visible and open up completely new possibilities in the transmission of science. The MROL experiments are an initial contribution to the investigation and further development of these possibilities. The visitor survey shows that the concept of the setting seems appropriate for achieving the goals of the first two transfer levels (making the discovery available, understanding the form of the ship) and that the connection between discovery and the scientific insight is at least in principle understood by most visitors. But it turns out that the mere experience of the discovery situation (wreck) is not adequate for a deeper understanding of the scientific processes and it seems that this requires supplementary information or interactions without a change of media[36].

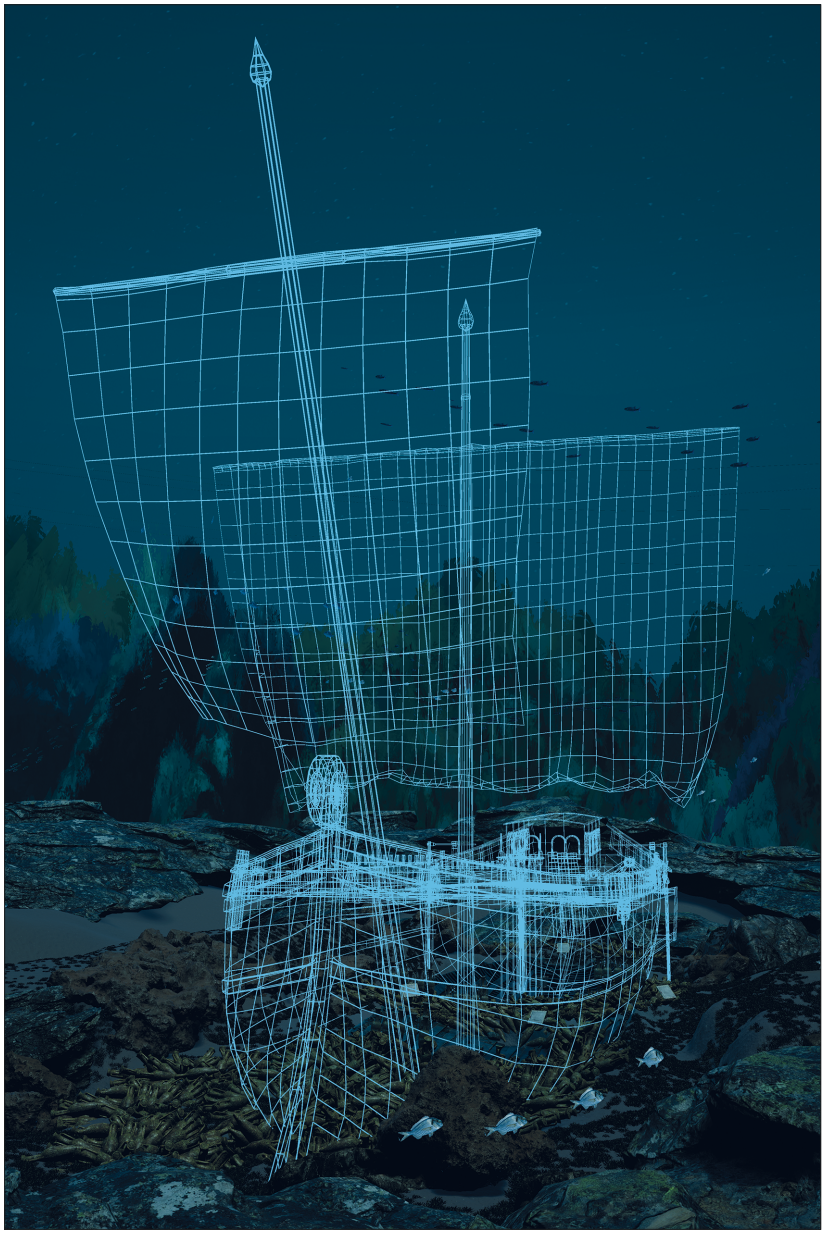

Fig. 17 Mixed Reality Open Lab 2018/2019: Virtual underwater world: realistic depiction of the wreck find and schematic reconstruction of the cargo ship. – (Still from the VR application: Beyond the Screen/Hochschule Mainz, F. Lotz, RGZM).

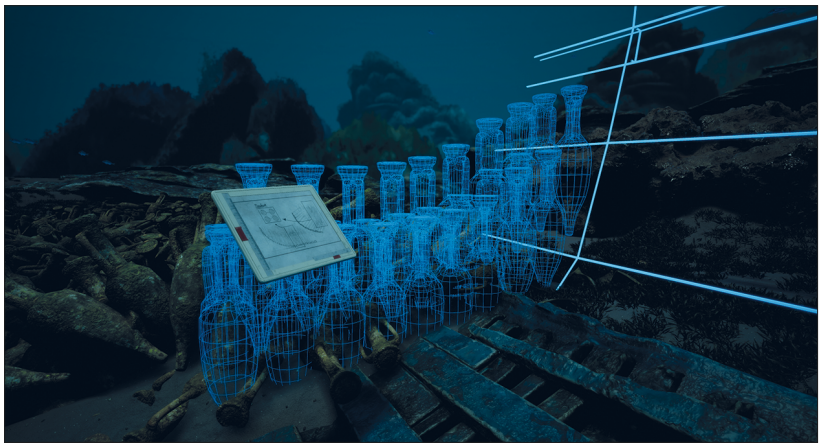

Fig. 18 Mixed Reality Open Lab 2018/2019: Virtual underwater world: schematic reconstruction of the loading situation of the amphoras. In the foreground a drafting board with the sketch of the reconstruction. In the background amphoras in the discovery site. – (Still from the VR application: Beyond the Screen/Hochschule Mainz, F. Lotz, RGZM).

Transparency, and as we believe, thereby credibility and authenticity, are generated in several ways in the experimental setting of the MROL in Mainz. The visitor of the virtual underwater world experiences two levels of reality. The highly realistic wreckage scene transmits the impression of actually being there. It constitutes the here and now for the visitor at this moment[37]. The wreck and its surrounding marine world were reconstructed from the extremely well documented archaeological evidence, excavation plans and countless underwater photos, as realistically and authentically as possible.
The reconstruction of the appearance of the ship as it might have been in Roman times is less clear. Parts of the wreck were certainly well preserved, but some, such as superstructures or rigging, were completely missing. They can only be reconstructed from comparisons. Therefore the ship reconstruction is represented only schematically, as in a draft model drawing but not photo-realistically. What is photo-realistically represented was actually found by the divers on the seabed. However, everything that researchers have merely reason to suppose is indicated with lines. Impressive nevertheless is this schematic reconstruction, as it unfolds life-size before the visitor on the 1 : 1 scale. It offers visitors space for their own interpretations and thoughts and has so far proved extremely popular. To what extent both, the realistic depiction of the wreck and the reconstruction, in the underwater world are credible and plausible for visitors is one component of the empirical studies in the context of the project (**figs 17-18**).

The presence of sources in the virtual world: the MROL example in Mainz

If the visitor wants to compare the virtual reconstructions with the evidence, the »authentic« sources, he changes the medium in the current Mainz MROL experimental setting. Immediately next to the VR-experience, a selection of original underwater images and plans can be seen on tablets or smartphones. There the visitor has the possibility of reading information at leisure and comparing the various levels of the reconstruction with their sources and references. Whether this succeeds and the implementation also generates in the visitor the desired understanding of the process of reconstruction and adequate credibility is part of the empirical visitor studies in the project. The images documentating the original archaeological evidence as well as further information to read and hear are provided through smartphones or tablets that are connected through NFC interfaces. Here a system of Tuomi GmbH, in Trier, is used. The data are centrally provided on a server and can be directly accessed through an internal Wifi network or an App. In this context it is tested how visitors use these media and how they must be designed to be used to optimal effect. In particular, it is assessed which information visitors retrieve, in what order and how much time they spend on this (**figs 19-20**).
Alternatively the user of the VR-experience could be shown original underwater images and stages of the scientists' work directly in the VR medium, so here in the headset. Considerations on this were not further implemented, as the design and programming expenditure in the current project would have been too high. It is to be expected that such a – closer – visual interconnection of the VR experience with its sources would generate in the user an even better understanding of the relationship between source and reconstruction.
Another challenge can be seen in a further issue: as there is no singular, definitive state of exposure during the excavation at most archaeological sites – and this is comparable to the restoration of objects – a special challenge in implementing the reconstruction of the Madrague de Giens wreck consisted in showing the various stages of exposure of the real underwater excavation. In order to save on processualities and »underwater actions« – and thus the vast programming expenditure exceeding resources – the wreck is made »accessible« to the visitor in a single »walkable« state of excavation. There the various stages of the excavation of the wreck are revealed at the same time. As the survey shows, this led – without showing ad-

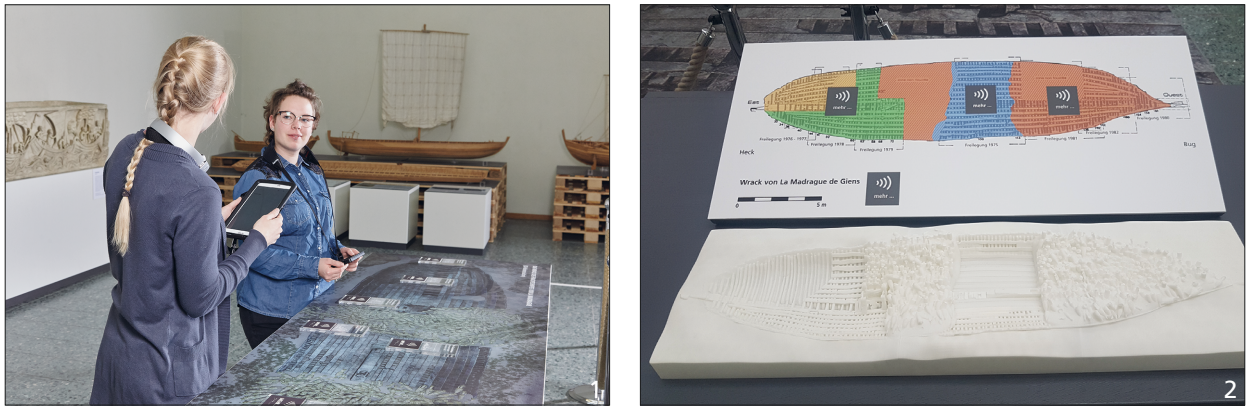

Fig. 19 **1** Mixed Reality Open Lab 2019: With a tablet or smartphone information to be read and heard about the wreck can be retrieved through an NFC interface. There is a specific audio guide for blind and partially sighted people. – **2** A 3D print of the ship wreck can be touched. NFC triggered information explains the phases of the excavation. – (1 photo R. Müller, RGZM; 2 photo D. Kimmel).

ditional explanations directly in the application – to comprehension problems in some users[38]. Through the »change of media« the information available through NFC at the time of the first survey was not easy enough to allocate in the virtual tour. In a first revision of the app a large virtual starting image of the wreck showing these stages was added therefore to the experience. An additional information interface directly in the virtual world would very probably ease this allocation further. As a solution an interactive virtual underwater map at the user's wrist showing his position and visual »signs« in the underwater feature has been conceptualized, but to date not been implemented.

Intuively understandable solutions for connecting a high-resolution immersion with reality for use in the museum would be a valuable field of future research and development, thereby always considering which information is best presented in the virtual world and which in reality or different media.

Fig. 20 Original relief of a Roman cargo vessel (RGZM inv. no. O.43097). Museum visitors can compare the reconstruction in the App with this secondary source. The relief can be touched and is also part of the inclusive information in the MROL setting. – (Photo R. Müller / V. Iserhardt, RGZM).

Fig. 21 Mixed Reality Open Lab 2018/2019: On a large screen it is possible to follow what the user with the VR specs is doing and where he is looking. In this way the virtual tour becomes a shared experience. – (Photo R. Müller, RGZM).

Fragile sources: special challenges for archaeology

In archaeology, models, reconstructions and other visualisations have a special importance for several reasons. First, artefacts are often extremely fragmentarily preserved or corroded. The same applies to archaeological features like buildings and infra-

structures. In many cases they have gone or are only still available in sparse remnants – especially in our climes – having either been constructed from perishable material such as wood or been destroyed or changed by subsequent use. Their former appearance is often difficult to interpret for the specialist, and generally incomprehensible to the layperson. Second, through excavations documented features are in many cases no longer visible after the work in the field. Third, in archaeology, at least regarding the more ancient times, other representations and sources such as paintings, manuscripts or photographs that could be used for explanation are often not or only to a limited extent available.
So in many cases we are reliant on more or less verified models, reconstructions and other visualisations if we want to form an image of the appearance and functioning of the archaeological evidence and want to transmit this understandably to visitors in the museum. Studies on the effect of models and digital reconstructions are therefore extremely important, specifically in an archaeological research museum. Given this special situation with sources, studies in the archaeological museum are also especially appropriate for dealing with converging hypotheses and investigating fragile *knowledge* in general[39].

Free experience or didactic guidance?

Observations in the operation show that museum visitors generally need – to differing degrees – instructions when using the applications. And, if the virtual experience is to claim to transmit to the visitor information or knowledge, beyond the enthusiasm for the new medium and the satisfaction of the urge to play, they also need – as with the real world – guidance and orientation. To what extent this is best carried out and how far choice and alternative possibilities in retrieving information are sensible would merit further investigation. A revised version of the underwater world that went into operation in 2019 therefore offers the possibility of accessing appropriate audio information through pressing virtual buttons during the experience. The effect of both variants, the version with audio explanations and the text-free version can thus be studied comparatively.

Digital media for inclusive museum development

Both the digital applications of the MROL are embedded in inclusively designed information about the ship and its investigation. By means of a special audio tour that can be accessed through smartphones or small tablets, as well as tactile elements, such as a 3D impression of the wreck find, the history of the ship can also be learned by blind and partially sighted people (**figs 19-20**). All visitors use the same media guide-system. The sighted visitor can select information by navigation on the tablet according to individual preferences, while the guide for the blind visitor has a linear structure. The user receives detailed instructions about the movement in the space, which are supported by a guiding system using a tactile strip on the floor. Developments by the industry to make Virtual und Augmented Reality usable for blind people as well sound highly promising and should also be further pursued for the museum context.

CONCLUSION: THE PATH TO MIXED AUTHENTICITY

As can be seen in the projects described, there are many kinds of possibilities for using realistic representations such as copies, replicas, models, reconstructions and immersive media – both material and digital – as

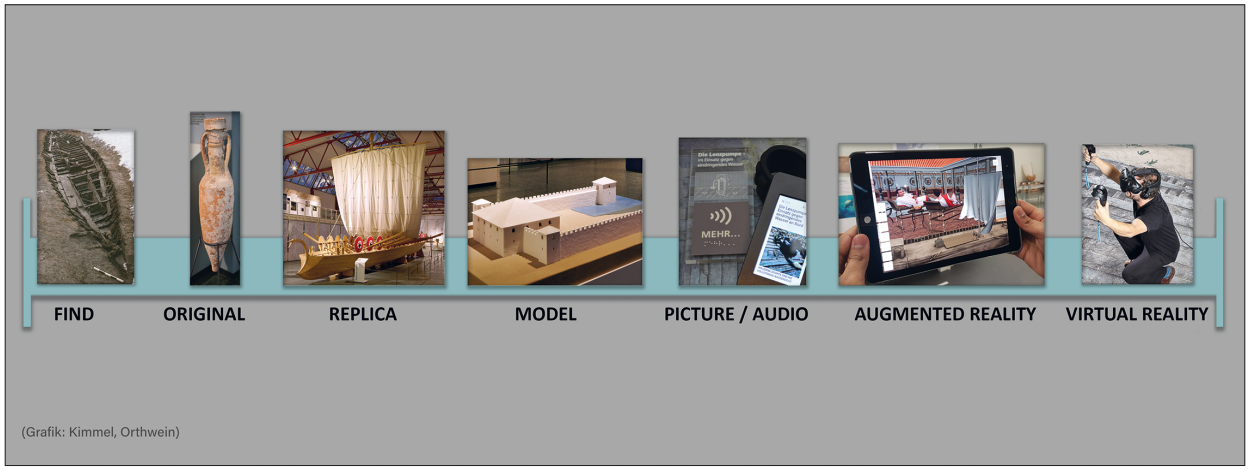

Fig. 22 Materiality and Virtuality. Objects and media used in museum and knowlegde transfer. – (Illustration D. Kimmel / M. Orthwein).

»substitutes« or in connection with original objects in the museums presentations and knowledge transfer. When objects and representations are used together, completely new dimensions can be achieved. Future discussions should therefore revolve less around where new digital media can replace objects or perhaps even the whole museum, and not merely how media can complement original objects, but much more around how these can be appropriately used together as equally valuable forms of presentation (**fig. 22**).
As described at the outset of this article, scientific discourse on the significance of authenticity in Museum und Cultural Heritage refers increasingly less to the authenticity of the object as its absolute characteristic but much more in a contructivistic way to the relativity of the authentic and the processes of verification and authentificating that give the object »authenticity«[40]. Against this background we suggest, also in connection with three-dimensional realistic representations, to distinguish in future no longer between two worlds *per se*: on the one hand, the real world of the »authentic« museum objects, on the other the world of the »non-authentic« – copies, reconstructions and digital media including Virtual Reality. We suggest expanding the concept introduced by Paul Milgram and Haruo Takemura in 1994 of the »Reality-virtuality continuum«[41], which in media research describes a continuous transition between the real and the virtual world, by two further dimensions: first, the »Object-originality continuum«, which describes the spectrum of »the originality« of museum things – from the original object, through the replica and the various forms of analogue reconstructions and forgeries, up to digital Augmented und Virtual Reality. Second, there is the »spectrum of verification«. It describes the degree of certainty of the knowledge that lies at the basis of the things and representations. The continuum is thereby in all three dimensions to be understood as a continuous scale between each of the two – only theoretical attainable – extremes or end-points. By analogy with »Mixed Reality«, which describes the connection between real and virtual world in the media context, we would therefore at this point like to propose the concept »Mixed Authenticity«.

Translation: Sophie Leighton

Notes

1) ICOM Code of Ethics for Museums: https://icom.museum/wp-content/uploads/2018/07/ICOM-code-En-web.pdf.

2) Thiemeyer 2015; 2016. – On the general importance of objects in the museum see also: Benjamin 1980; Korff 1992. – For an overview of the current literature see also Sabrow/Saupe 2016.

3) Hampp/Schwan 2017, 90; Only a number of pieces of art were exclusively created for the museum.

4) Including by several authors in this volume; on the discussion about the multidimensional nature and relativity of authenticity see among others: Eser et al. 2017b, 1; Foster/Blackwell/Goldberg 2014; Latour/Lowe 2011.

5) For the significance of replica see also: Foster/Curtis 2016.

6) Hampp/Schwan 2017, 90.

7) Bekele et al. 2018.

8) Wirth et al. 2007.

9) Orthwein 2014.

10) Orthwein 2014, 333.

11) Challenor/Ma 2019, 39.

12) The projects are also a contribution to research conducted by the Leibniz Research Alliance Historical Authenticity founded in 2012.

13) As a continuation of the work in the Mixed Reality Open Lab, the Advanced Immersive Media-Lab (AIM-LAB) was founded by Prof. Michael Orthwein at the Hochschule Mainz in 2019.

14) For a more detailed description of these and other projects up to 2015, see also: Orthwein 2015.

15) Scientific head: Dominik Kimmel (RGZM), Michael Orthwein (Hochschule Mainz), Stephan Schwan (Leibniz-Institut für Wissensmedien) und Ronald Bockius (RGZM); technical coordinator: Ferdinand Lotz. – The following students of »Beyond the Screen« (Hochschule Mainz) were involved in the development: Roxana Löwenstein, Aaron Franz, David Krick, Max Zink, Jochen Funk, Erfan Mehdibeiraghdar, Corbin Sassen, Jan Duran, Timur Ariman, Jannis Oing, Larissa Joos. – Project participants at the RGZM: Thomas Schmidts, Antje Kluge-Pinsker, Ingrid Schmidts-Jütting, Sandra Hahn, Cecilia Plichta, Sabrina Bockius, Till Müller, Peter Werther, Katja Hölzl, Werner Vollrath. – External partners: Łukasz Kołodziejczyk, Anna Preiss.

16) All the studies took place in the context of close collaboration between the archaeological experts, designers and programmers. Our thanks go especially to the colleagues in the Forschungsbereich Antike Schifffahrt and in the Museum für Antike Schifffahrt des RGZM.

17) An exhibition in the context of Mainz Stadt der Wissenschaft (city of science), 2011.

18) Described in the letter from Pliny the Younger to Tacitus (Pliny, Epistulae VI, 16).

19) Prof. Dr. Thomas Riepert, Institut für Rechtsmedizin, Johannes Gutenberg-Universität Mainz.

20) Kimmel/Mangelsen 2018; Ettel et al. 2014; see Fossa Carolina in the DFG Priority Programme 1630 »Häfen von der Römischen Kaiserzeit bis zum Mittelalter«: www.spp-haefen.de/en/projects/fossa-carolina/ (22.07.2020).

21) The ship find was examined from 1972 to 1982 in an elaborate underwater excavation by the Centre Camille Jullian, an institute of the Centre national de la recherche scientifique (CNRS) and today's Aix-Marseille University.

22) On the possibilities for interaction, see among others the following papers generated in the context of the collaboration at the Hochschule in Mainz: Lotz 2017.

23) Documented by recording (tracking) the users' virtual movement activity. Unpublished results of the study.

24) Unpublished results of the study 2019.

25) A. Franz, mentor M. Orthwein; archaeological participation R. Bockius, P. Werther, RGZM; Franz 2019.

26) Zabel 2014.

27) Stahl 2015.

28) Further studies at the chair of M. Orthwein on this subject among others: Sebastian Freigang, Methoden zur Architekturrekonstruktion anhand von 3D Laserscandaten mit Vergleichen zu bildbasiertem Modelling am Beispiel der Michaelskirche zu Fulda [unpubl. diploma thesis, Hochschule Mainz 2009]; Yannick Petrak, »Creatures of Light«. VR Visualisierung einer Ausstellungs-Station [unpubl. bachelor thesis, Hochschule Mainz 2016]; Leopold Lotz, »Chronos«. Ein Anforderungskatalog für Interaktion im Virtuellen Raum [unpubl. bachelor thesis, Hochschule Mainz 2017]; Alexander Oster »Virtual Senckenberg«, Virtual Reality als Ausstellungsform [unpubl. master thesis, Hochschule Mainz, 2016]; David Krick, »Advanced Augmented Reality Escape Room«. Ein Beispiel für die Interaktion im Virtuellen Raum [unpubl. bachelor thesis, Hochschule Mainz 2019]; Aaron Franz, »Remigatio«. Ein Lösungsansatz zur Haptik in der virtuellen Realität [unpubl. bachelor thesis, Hochschule Mainz, 2018]; Moritz Krutzke, »Visualising Science«. 3D-Animationen in der Wissenschaft [unpubl. bachelor thesis, Hochschule Mainz, 2014]; Moritz Krutzke, »Experiencing Science«. Film und Virtual Reality in der Wissenschaft [unpubl. master thesis, Hochschule Mainz, 2018]; Corbin Sassen »Looking for Home«. Visualisierung des Themas Zuhause in Virtual-Reality [unpubl. bachelor thesis, Hochschule Mainz, 2018]; Sebastian Veres, »Cinematic VR Experience«. Einsatz von Licht in VR-Applikationen [unpubl. bachelor thesis, Hochschule Mainz, 2018].

29) See e. g. Attwood et al. 2018, 151; Bunce 2016; Di Franco et al. 2015; Turner et al. 2017; Wilson et al. 2017; 2018; Schwan et al. 2017; Hampp/Schwan 2014; 2015.

30) Mangelsen 2015.

31) Hochschule Mainz, Ch. Reichhardt, Option Kulturmanagement 2015; documentation J. Zachmann.

32) Unpublished study 2019 by S. Hahn / D. Kimmel / S. Schwan, publication in preparation.

33) The study and first data analyses was carried out by S. Hahn with the authors' participation, unpublished study 2019.

34) Leibniz Research Alliance Historical Authenticity, project »Original, Modell und Virtuell Reality – Vermittlung wissenschaftlicher Erkenntnis im Museum. Publikumsforschungen am Beispiel herausragender archäologischer Objekte«.

35) Glaser/Schwan 2019; see also Jones 2018, 333-353. – On benchmark standards in heritage visualization see »The London Charter«, 2009: www.londoncharter.org (22.07.2020).

36) The unpublished 2019 study shows the following scores: The average rating for the statement, »I understand the archaeological find as a source of scientific work« at 3.65 is clearly higher than the rating for the statement, »The VR application shows me how archaeologists work« (2.69). The rating for the statement »The VR application helps me to understand how a ship reconstruction arises« is in between at 3.35. (On the scale of 1 [I do not agree at all] to 5 [I completely agree].

37) Wirth et al. 2007, 493-525.

38) Hahn, unpublished Data Analysis, 2019.

39) Schwan/Grajal/Lewalter 2014.

40) See note 4.

41) Milgram et al. 1994.

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Zusammenfassung / Summary

Zwischen Realität und Virtualität. Untersuchungen zur Authentizität realitätsnaher Darstellungen in der musealen Vermittlung

Die sich rasant weiterentwickelnden digitalen Medientechnologien wie Virtual oder Augmented Reality ermöglichen dreidimensionale Darstellungen und immersive Erlebnisse in immer realitätsnäherer Perfektion. Auch in der musealen Vermittlung werden diese zunehmend eingesetzt: bei der Herstellung digitaler Kopien, der Rekonstruktion zerstörter Objekte oder vergangener Befunde bis zur Darstellung komplexer Kontexte und ganzer Szenerien. Dabei entstehen neue Herausforderungen an der Schnittstelle zwischen den technischen Möglichkeiten und dem Anspruch an eine »authentische« und glaubwürdige Vermittlung von Wissenschaft und Forschung. Der Artikel bietet einen Überblick über eine Reihe von Herausforderungen und Fragestellungen im Zusammenhang mit den Anwendungsmöglichkeiten von materiellen und digitalen realitätsnahen Darstellungen in der musealen Vermittlung und ihrer Wirkung beim Museumsbesucher, mit denen sich die Autoren im Rahmen von verschiedenen experimentellen Szenarien und empirischen Untersuchungen, insbesondere am Römisch-Germanischen Zentralmuseum in Mainz, zwischen 2011 und 2019 befasst haben.

Between Reality and Virtuality. Studies on the Authenticity of Realistic Depictions in Museum Learning

Rapidly developing digital media technologies such as virtual or augmented reality enable three-dimensional representations and immersive experiences to an ever more realistic degree. They are also increasingly used in museum learning: from the production of digital copies, the reconstruction of destroyed objects or past finds to the representation of complex contexts and entire scenes. In the process, new challenges arise at the interface between the technical possibilities and the demand for an »authentic« and credible means of transferring scientific knowledge and research. The article provides an overview of a number of challenges and questions related to the possible applications of realistic material and digital representations in museum learning and their effect on the museum visitor. The authors have dealt with these challenges and questions in the context of various experimental scenarios and empirical studies, in particular at the Römisch-Germanisches Zentralmuseum in Mainz between 2011 and 2019.