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RiftArt: Bringing Masterpieces in the Classroom through Immersive Virtual Reality

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Abstract

The recent development in consumer hardware lowers the cost barrier for adopting immersive Virtual Reality (VR) solutions, which could be an option for classroom use in the near future. In this paper, we introduce RiftArt, a VR tool for supporting the teaching and studying of Art History. Using RiftArt the teachers can configure virtual museum rooms, with artwork models inside, and enhance them with multimodal annotation. The environment supports both the teachers during the lesson and the students during rehearsal. The application, implemented completely using Web technologies, can be visualized on large screens and head mounted displays. The user test results advance the understanding of the VR effects on classroom usage. We demonstrate that VR increases the motivation of high-school students towards studying Art History and we provide an in-depth analysis of the factors that contribute to this result.

1. Introduction

Training and learning were two of the most important applications of virtual reality (VR) since the first introduction of technologies supporting the creation of virtual environments. Already in the 1980's, VR was used to replicate dangerous or safety-critical settings (e.g., airplane cockpits, space exploration etc.), or simulated contexts impossible to sense directly (e.g., cell evolutions, atomic reactions etc.) [Haw95, You98]. At the time the hardware was really expensive and its cost was worth only if compensated by other relevant aspects like, for instance, the safety of air traffic. As the personal computers expanded their computational power, desktop-based solutions provided VR environments at a reasonable cost since many years, increasing the learner's engagement even if providing a less immersive experience [Dic03].

Nowadays, the technology evolution has led to the creation and commercialization of different consumer-level devices allowing to create immersive experiences at a reasonable cost, and we foresee that the availability of such hardware will increase in the next future. For instance, the Oculus Rift [Ocu], represents the first customer-level VR head mounted display (HMD) for gaming. Other mobile-based HMDs are currently under development, (e.g., the Samsung Gear VR [Sam]), while very cheap solutions for transforming mobile phones into HMDs [Goo] already exist.

Technology is ready for employing immersive VR experiences in classrooms, in the near future, for teaching more subjects than those covered in the past by VR environments. In this paper, we describe the setup of RiftArt, a VR environment for teaching Art History. It is thought for creating teaching materials to compare two or more artworks, putting them in the same virtual room. The teacher prepares different multimedia contents (e.g., audio or text descriptions), for highlighting and describing different aspects of the artwork. This material may be used both during the lesson and also for individual study. The students can explore the artwork, both using wide shared displays, but also using HMDs, thus replicating the visit in a (virtual) museum room.

In the following sections we describe both the RiftArt supported features, the user experience provided and the implementation's technical details, which are useful for researchers and practitioners that would like to create similar experiences through web-based solutions.

In addition we report on a user test, which provides insights on the adoption of immersive VR as teaching material. We measured the students' motivation in learning a particular Art History topic through the Instructional Material Motivation Survey instrument (IMMS) [Kel09], comparing the immersive VR against a projected shared display (which is the current standard in Italian classrooms) on two different groups of high school students. The results show that the

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VR setting increases their motivation. We analyse in detail the factors that ground such difference.

2. Related work

There is an extensive research literature on VR application to teaching and learning. Merchant et al. [MGC*14] provide a review on the effectiveness of VR-based instruction in elementary, middle and high school. They classify the VR environments in three categories: i) simulations, which are interactive digital environments imitating real-life processes and situations; ii) games, which are special simulation environments which include goals, achievements and levels to be reached following narrative plots; iii) virtual worlds, which exploit the illusion to be in a 3D space, the ability to interact with 3D objects, the avatar representation of the learner and communication with other users inside the world.

VR has been adopted in different areas for teaching, especially when allowing the action of inexpert people may cause danger or may raise ethical issues. For instance, in [DMM08] the authors exploited the VR for medical education, taking advantage of the reduced risks and costs, together with the possibility to instruct students from a distance. The research community studied such advantages, analysing the effectiveness of web-based multi-user virtual environments from a pedagogical point of view [CR07], and comparing them against 2D alternatives [DL10]. Most of the studies focused more desktop-based virtual environments with respect to more expensive settings like cave automatic virtual environments (CAVEs) or HMDs.

The already mentioned availability of hardware supporting immersive experiences led to a new generation in learning environments, exploiting the increased fidelity perceived by users [BWR14]. Both the topic and the target audience vary: veterinary anatomy [VNMB14], architecture and building engineering [VFD14] for university students, biology for K-8 students [LSP14] and even subway evacuation procedures for a larger audience [SJMS14]. We are interested to analyse the effect of adopting an immersive setting not only on the perceived fidelity of the environment, but also on the impact on student's motivation towards a specific topic.

The application of VR in the art and cultural heritage field had different purposes, e.g. the acquisition for preserving [LPC*00] or restoring [GRZ04] artworks; the reconstruction of a 3D scene from a painting or fresco [CEB*14] and more. There are different examples of educational VR-based applications that foster informal learning, especially in museums, where providing a playful interactive experience is crucial for attracting people, especially children. For instance, already in 2000 at the Foundation of the Hellenic World in Athens was possible to take a virtual guided tour in both Olympia and the ancient Miletus [GCVR00]. More recently, Kennedy et al. [KFM*13] reconstructed the St. Andrews Cathedral, which can be virtually visited with Oculus Rift. In addition, VR empowered the creation of virtual museums and exhibitions. In [SFKP09], the authors survey such applications describing different implementation settings and technologies. They define a virtual learning museums as a specific type of virtual museum, which presents contents in a context and interest dependent way, in order to motivate a real visit and stimulate the curiosity on contents that better fits the user's interest.

In this paper, we focus on a different type of VR application, which provides material for a formal lesson on Art History and cultural heritage. Exploiting VR for creating such kind of material has been under investigated by the research community considering again the high hardware cost for a classroom set-up.

3. RiftArt prototype

The exhibition curators accurately select the artwork position inside a museum, in order to ease the interpretation of sculptures and paintings following a reasoned path inside a specific period of time or the life of an artist. Similarly, teachers try to follow a logical path in their explanations, in order to highlight the main characteristics of genre, similarities and differences in execution techniques etc. However, if is it easy compare two sculptures in a specific place, for example the Canova's work “Amor and Psyche" and the “Venus de Milo" at the Louvre museum, it is hard to do the same thing comparing artworks located in different places, especially for those artists that had a great impact and worked in different cities and countries. For instance, consider Michelangelo's “David" and the “Moses": the two masterpieces are located in different cities (the former in Florence and the latter in Rome), and they have very different sizes (410 cm vs 235 cm). The obvious solution to such physical problems is using photos of the whole sculpture and details for showing the students the artwork characteristics.

Considering the state of 3D scanning techniques and the advances in the simplification and manipulation of such large datasets, our idea is to complement such teaching material with a VR environment, where the teacher can position 3D models two or more sculptures in a virtual museum room. Such material would be available during the lesson, in order to support the teacher while explaining the concepts. In addition, it can be provided to students for autonomous study.

This is the main idea of the prototype tool we discuss in this paper, named RiftArt: empowering teachers with the possibility to create VR environments as teaching material. As we better detail in the evaluation section, the possibility to explore the environment through the Oculus Rift HMD has a positive impact on the student's motivation. In the next two sections, we discuss first the interaction supported by the prototype and then its technical implementation.

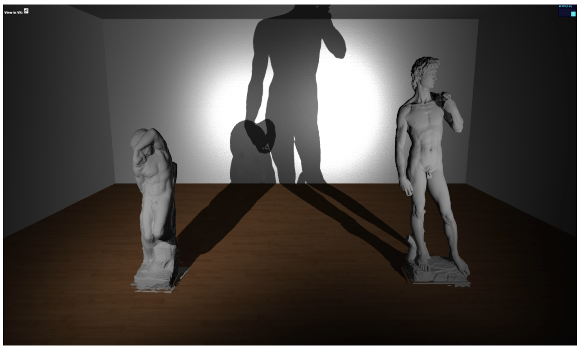

Figure 1: *RiftArt interface*

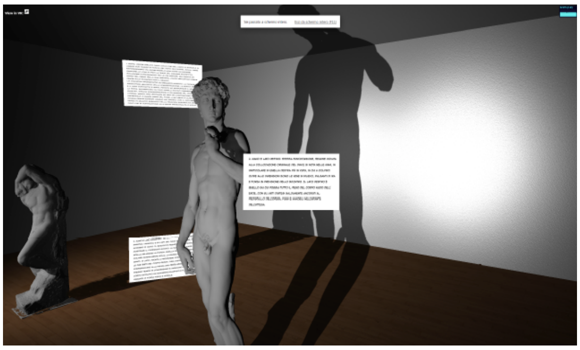

Figure 2: *Textual annotations on artworks.*

3.1. Interface

Figure 1 shows the main RiftArt interface: the user sees a virtual museum room where it is possible to explore two sculptures. In our example, we have two Michelangelo's masterpieces: the "David" (1501-1504) and the "Youthful Captive" (1530-1534). The 3D models were provided by the Stanford Digital Michelangelo project [LPC*00].

The user can freely move inside the room changing the position of the camera in all directions, enabling her to admire every sculpture detail. Obviously, the tool supports different levels of scene configuration. First of all, it is possible to load different models, which can be selected according to the lesson topic. In addition, the teacher can control their position inside the room and their orientation. Moreover, it is possible to set a scale factor for the different models, in order to allow the comparison of sculptures with a relevant difference in size. Such feature breaks the environment fidelity with respect to the real counterparts, creating experiences that can create misconceptions in students. Therefore, teachers should use such feature carefully.

The virtual museum room was designed in order to minimize its interference with the inner content. It consists of four plain walls, a single wooden floor and a plain ceiling, whose dimensions depend on the size of the artwork models. It is possible to configure the position of several spotlights directing them towards the sculpture model. The tool proposes a default light configuration that can be modified by teachers, in order to enhance the virtual visit experience or for highlighting relevant details of the artwork.

Once the teacher has configured the environment, RiftArt allows users to visit the virtual room, moving the user's viewpoint with the standard keyboard and mouse coordinated control for first person video games.

The environment allows associating multimedia annotations to the whole sculpture or to parts of it. In this way, the teacher augments the artwork visualisation through a different contents, useful for e.g. individual lesson rehearsal. Notes may be either audio or textual. Textual notes can be easily read from different point of view, since their orientation is based on the user's point of view, as shown in figure 2. In the same way it is possible to activate audio notes, that play pre-recorded audio descriptions, focusing the user's attention on a specific detail with a cone-shaped pin, as shown in figure 3. We do not include videos directly in the visualisation, but they may be linked through text annotations.

The annotations are associated to keyboard buttons, the list of associations is available pressing the L button. When the user activates an annotation, the tool provides automatically moves her position in the scene in order to visualise the artwork detail.

RiftArt allows users to explore the virtual environment through two different types of displays. The first one provides a monocular view on the 3D scene, suitable for normal displays. Such visualisation is useful for the currently adopted technology setting in Italian classrooms, which are currently provided with an interactive multimedia whiteboard (LIM): a wide projected screen where it is possible to interact through touch gestures or drawing on the surface through special pens. With such display configuration, RiftArt supports the teacher in showing the students the artworks and commenting on particular details. The viewpoint is controlled by the teacher through a remote, a keyboard or through multitouch gestures. The teacher may use audio or video annotations if needed.

The second visualisation option allows to explore the artworks with a consumer VR HMD, such as the Oculus Rift or Google Cardboard. In this case, the tool provides a stereoscopic view on the environment, increasing the sense of immersion in the virtual environment and the depth perception. In this case, the user has two points of view on the scene, one for the left eye and one for the right eye, as shown in figure 4. The user controls only the position in the room through the keyboard, while she freely moves and rotates her head in order to change the looking direction, exploiting the inertial sensors in the HMD. A video showing such interaction is available at `https://goo.gl/0lSh1T`.

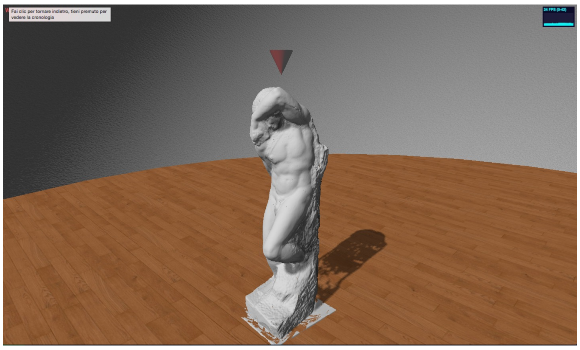

Figure 3: *Audio annotations on artworks. A pointer focuses the user's attention on the part described by the audio recording.*

As we better detail in the following section, the tool implementation is web-based. Therefore, it is possible to support a scenario where all students wear an HMD and the teacher coordinates the lesson content. However, considering the currently technology status and cost, such configuration is not realistic even if technically possible. The HMD visualisation may be currently used for autonomous study or lesson rehearsal. However, considering that it is already possible to use high-end smartphones as VR viewers, we suppose that this scenario will be realistic in a near future, either using school equipment (e.g. setting-up a laboratory) or directly exploiting student's personal devices

3.2. Implementation

Considering that the application provides teaching material to students, it is quite obvious that it should be accessible from different devices and in different places (e.g. at school, at home, etc.). As happens for other multimedia contents, web-based implementations provide the flexibility for supporting different users and devices. We select to exploit a completely web-based solution since it provides two advantages over gaming platforms such as Unity or Unreal. The first one is the possibility to include the 3D visualization inside other web contents, such as e.g. the school website information, or a museum description. In this way, it would be possible to reuse the environment not only for teaching purposes, but also for providing general or additional information on artworks. The second advantage is the opportunity of updating contents without reinstalling any application, which is important for supporting teachers in creating their own contents (e.g. through an authoring environment), with a quick cycle.

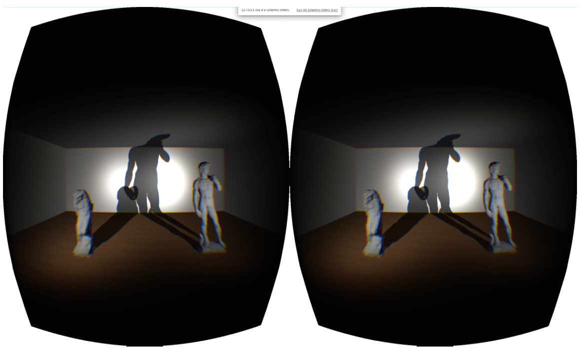

Figure 4: *Stereoscopic view on artworks.*

Therefore, we chose to implement a web application that uses WebGL [Krob] (Web Graphics Library) for creating the virtual environment. WebGL is a low level JavaScript API for rendering interactive both 2D and 3D computer graphics, based on OpenGL ES 2.0 [Kroa]. In order to avoid using low-level drawing functions, we created the scene using the `Three.js` [Jav] library, which provides loaders for different 3D model formats, geometries, materials, lights, cameras etc. Using WebGL and Three.js guarantees the compatibility with the most important browsers (Chrome, Firefox, Opera, Internet Explorer, Safari) in both their desktop and mobile versions.

We support the single camera display (the LIM mode) with a perspective camera, with a 45° field of view. In order to move inside the word, the user changes the position of the camera or the sight direction with the keyboard and mouse.

The support for the HMD requires two components. The first is a renderer that creates the image for each eye. A VR effect decorator wraps the usual 3D scene renderer object, and it is provided by Three.js. Starting from the current position of a normal perspective camera, the decorator shifts its position to the left and to the right for simulating a separate camera for each eye, and then it renders the corresponding images splitting the screen as shown in figure 4.

The second component is required in order to change the camera orientation in the scene according to the user's head movements. In order to do this, the browser must read the HMD sensor data, whose access is not currently provided by any desktop browser out of the box. In order to use the Oculus Rift with a desktop browser there are two alternatives: the first is a special build of the Chromium browser (named Chromium VR) and the second is the development Firefox nightly build. Considering mobile devices, Chrome for Android supports natively the Google Cardboard.

In order to enable the VR visualisation, the application checks that the client is a VR compatible browser, and, if it is not, the user can runs only the monoscopic version. If the browser supports the VR, it checks if there is an available HMD on desktop computer or if the device is compatible with Google Cardboard on mobile. If so, the stereoscopic visualisation can be activated simply pressing a button, which is invisible otherwise.

Figure 5: *Virtual room rendering in fast mode.*

Even if the web-based visualisation guarantees the flexibility in accessing the tool through different devices and operating systems, the differences in the hardware configuration have a high impact on the user's experience. The 3D rendering is obviously more resource consuming with respect to regular web pages and, especially when RiftArt is used with HMDs, the tool should update the scene with a mean frame higher than 24. However, the number of the 3D models in the scene, their resolution, the number and the type light type may degrade the rendering performance especially on mobile devices. Therefore, the tool is able to render the scene in two modes:

- In the *High Fidelity Mode*, RiftArt configures the scene using more realistic but computationally expensive elements, such as more high resolution models, more than one light source and so on.
- In the *Fast Rendering Mode*, RiftArt includes the models version with the lowest resolution (if provided), only one directional light following the camera direction and a spherical version of the museum room for avoiding unpleasant light reflections.

Figure 1 shows the rendering in the high fidelity mode, while figure 5 shows the same scene rendered in fast mode.

4. Evaluation

In order to assess the prototype effectiveness as a teaching support, we decided to evaluate its effects on students motivation, which has been defined as "that which explains what goals people choose to pursue and how actively or intensely they pursue them" [Kel09, p.1]. Different studies related the student's motivation and performance [The99, Kel09]. In this paper, we replicated the study in [SIK13], which exploits the Instructional Material Motivation Survey Instrument (IMMS) [Kel09] for evaluating the motivation according to four different factors, namely *Attention*, *Relevance*, *Confidence*, and *Satisfaction* (ARCS) [Kel87]. The main difference with respect to the work by Di Serio et al. [SIK13] is the setting type: while they analysed the Augmented Reality effect on motivation, here we analyse the effect of Virtual Reality (VR).

4.1. Method

Through the following user test, we aim at testing the hypothesis that the immersive VR setting described in this paper is able to increase the motivation of students. Therefore, we compared our setting against the technology environment currently available in Italian high schools: the LIM, a projection-based widescreen with multitouch capabilities connected with a PC.

An expert on Art History prepared a lesson on Michelangelo's sculpting technique, to be supported with RiftArt (we provided only the technical support for creating the material). She inserted in the environment an example of his early years as an artist, the well-known David, and an example of his mature phase, the Youthful Captive. For each sculpture, she included a general description, and a more detailed explanation of three different artwork parts: the head, the left and right arm for the David, the head, the right arm and the right leg for the Youthful. All such information has been recorded in advance, reading texts provided by the Art History expert. A set of keyboard buttons activated the playback of the different audio descriptions.

In order to evaluate the effects of using a VR environment, we exploited the monocular and the binocular view provided by the RiftArt prototype respectively for the LIM (not immersive) and the Oculus Rift version. Since the information provided is the same in both version, with this setting we are able to run the experiment controlling two conditions: VR versus LIM.

The test was hosted in a high school, the Liceo Filippo Figari in Sassari, Italy, which has a specific programme in Arts. We selected two different classes: all the students in the first attended the lesson taught with the LIM (and they represented our control group), while the second class attended the Oculus supported lesson.

At the end of each lesson, we requested the participants to fill a questionnaire in three parts: demographic information, the IMMS [Kel09], which allows to evaluate the overall motivation of the students through a set of 36 questions, grouped according to the four factors that lead the human motivation [Kel87] for learning:

- **Attention**: Capturing the interest of learners; stimulating the curiosity to learn.
- **Relevance**: Meeting the personal needs/ goals of the learner to effect a positive attitude.
- **Confidence**: Helping the learners believe/ feel that they will succeed and control their success.
- **Satisfaction**: Reinforcing accomplishment with rewards (internal and external).

The questionnarie contains 36 questions, each one in a 1 to 5 Likert scale. Reversing the ratings for questions with a negative formulation and aggregating the points, it is possible to analyse each one of the ARCS factor individually, since each question is associated with one of them.

Considering that we run the test during school time, we did not have the time for requesting students to complete some exercises at the end of the lesson. Therefore, we removed the exercises related questions from the questionnaire (namely question 5, 19 and 27). Two of the questions we omitted are associated to *Satisfaction*, while one is associated to the *Confidence*.

In summary, the maximum aggregate score in the modified version is 165 (instead of 180). The maximum scores for the four factor are: 60 for the *Attention*, 45 for the *Relevance*, 40 (instead of 45) for the *Confidence* and 20 (instead of 30) for the *Satisfaction*.

Besides evaluating the students motivation, we included five additional question for evaluating a set of qualitative aspects more related to the tool usability, such as aesthetics, usefulness, enjoyableness, simplicity and will to reuse the environment. These additional questions complete the evaluation since the IMMS questionnaire is focused on learning rather than usability.

4.2. Results

Twenty-three people participated to the user test. Twelve tested the LIM ($G1$), while the remaining tested the Oculus version ($G2$). The LIM group was one year older than the Oculus group ($\bar{x}_{G1} = 18.58, s_{G1} = 1.38, \bar{x}_{G2} = 17.27, s_{G2} = 1.01$). The LIM group had moderate experience with 3D environments and 3 of them already used HMDs. In G2 none of the participants already used HMDs, and they have less experience with 3D environments if compared to G1.

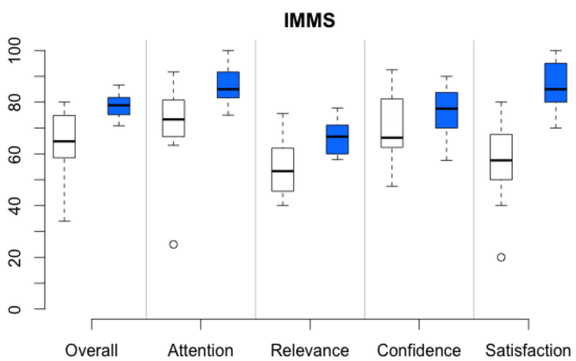

Figure 6: *IMMS aggregated scores (normalised by the maximum value for each category). The white boxes represent the results for G1 (LIM), while blue boxes represent the results for G2 (Oculus).*

Table 1 shows the aggregated scores means given by $G1$ and $G2$ for the whole IMMS questionnaire (indicated in table 1 as Motivation) and for each one of the ARCS factors. In order to compare the two groups, we used the Student's t-test for independent samples ($\alpha = .05$). We ensured that the measures for each group are normally distributed running a Shapiro-Welch test. We had to reject the normality hypothesis only for the G1 *Attention* data, we fixed the problem simply excluding an outlier value.

Question	G1 (LIM)	G2 (Oculus)	95% c.i.	p
Motivation	$\bar{x} = 106.7$ $s = 20.53$	$\bar{x} = 129.6$ $s = 8.30$	[9.23; 30.70]	.002
Attention	$\bar{x} = 45.27$ $s = 10.18$	$\bar{x} = 52.00$ $s = 5.11$	[2.01; 11.44]	.013
Relevance	$\bar{x} = 24.42$ $s = 5.05$	$\bar{x} = 30.00$ $s = 3.06$	[1.96; 9.21]	.004
Confidence	$\bar{x} = 28.17$ $s = 5.34$	$\bar{x} = 30.36$ $s = 4.36$	[−2.02; 6.41]	.291
Satisfaction	$\bar{x} = 11.33$ $s = 3.26$	$\bar{x} = 17.27$ $s = 1.95$	[3.61; 8.27]	.000

Table 1: *IMMS aggregated scores for the whole test (Motivation) and for each one of the ARCS factors. We highlighted in bold the ones with significant differences. For each factor we report the mean value ($\bar{x}$), the standard deviation (s), the 95% confidence interval around the mean (95% c.i.) and the p value.*

The t-test highlighted a significantly higher mean score for the Oculus version for the overall motivation, ranging between 9 and 30 points. Such result confirms our hypothesis: the motivation of the students is higher if we use VR for presenting the teaching material, with respect to the technology setting currently employed in Italian high schools.

We can analyse more in detail the results for the ARCS factors, which are depicted in figure 6. We found a significant higher difference for three out of four factors. The difference for *Confidence* factor, even if the mean is higher in the G2 group, does not allow us to conclude that the VR or the LIM setting has an impact on the students' expectancy of success or control feeling on the subject.

In summary, we can draw the following conclusions from the IMMS result analysis:

- Using a VR setting has a positive impact on the students' interest in the lesson topic (*Attention* factor). Since the lesson contents were the same in the two versions (the 3D models or the audio descriptions), the advantage can be explained only in terms of the technology setting.
- The VR setting led to a higher satisfaction for students attending the lesson (the *Satisfaction*). This point requires

more investigation: the satisfaction may be explained with the sense of novelty deriving from using a new technology for the first time, but we cannot exclude that this feeling may decrease in the long term.

- The VR setting increases the feeling that the lesson material fits the student's need (*Relevance*). The stereoscopic visualization of sculptures provided by the Oculus Rift allows the students to better appreciate the details of an artwork, therefore they have a sensation closer to a real museum visit. For instance, the students that tried the Oculus version were much more impressed by the smoothing difference between the David and the Youthful Captive with respect to the other ones.

The second part of the questionnaire included five questions evaluating five qualitative aspects of RiftArt: aesthetics, usefulness, enjoyableness, simplicity and their wish to reuse the application. All questions requested a 1 to 7 Likert scale rating. As shown in figure 7, the ratings for the Oculus version are higher for all aspects considered.

More in detail, table 2 shows the results of the means comparison through a t-test ($\alpha = 0.05$). The differences are all significant, however the confidence interval for the aesthetics in the worst case may be not practically relevant. For all the other aspects, the students consistently prefer the Oculus version.

Question	G1 (LIM)	G2 (Oculus)	95% c.i.	p
Aesthetics	$\bar{x} = 3.83$ $s = 1.26$	$\bar{x} = 5.11$ $s = 1.27$	$[0.10; 2.46]$	.035
Userfullness	$\bar{x} = 5.08$ $s = 1.93$	$\bar{x} = 6.67$ $s = 0.50$	$[0.33; 2.84]$	.017
Entertainment	$\bar{x} = 4.00$ $s = 2.13$	$\bar{x} = 6.67$ $s = 0.50$	$[1.28; 4.05]$	.001
Simplicity	$\bar{x} = 4.08$ $s = 1.78$	$\bar{x} = 6.00$ $s = 0.87$	$[0.67; 3.16]$	.005
Reuse	$\bar{x} = 4.58$ $s = 2.35$	$\bar{x} = 6.67$ $s = 0.50$	$[0.56; 3.60]$	.011

Table 2: *Qualitative questionnaire results comparison. For each aspect we report the mean value ($\bar{x}$), the standard deviation (s), the 95% confidence interval around the mean (95% c.i.) and the p value.*

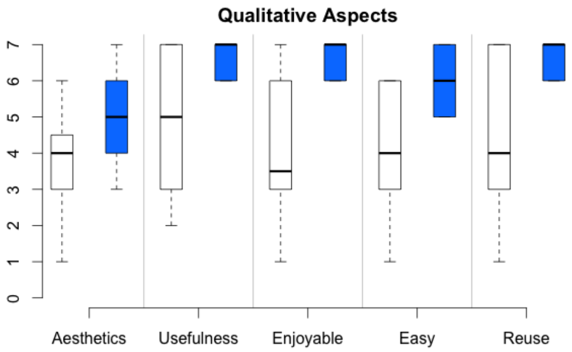

Figure 7: *Summary of the qualitative question scores. The white boxes represent the results for G1 (LIM), while blue boxes represent the results for G2 (Oculus).*

5. Conclusion and future work

In this paper we introduced RiftArt, a tool supporting teaching and studying Art History through Virtual Reality. With RiftArt, teachers can exploit 3D models for describing and comparing different artworks. In addition, they can enhance them through multimedia annotations. The same material can be used by students for individual learning. RiftArt has been developed completely with web-based technologies, in order to be accessible from different devices. We discussed the technical solutions, their advantages and disadvantages. The prototype can be used on wide shared screens, such as LIMs (the multimedia whiteboard currently employed in Italian classrooms), but also on recent consumer level head mounted displays, such as the Oculus Rift or the Google Cardboard. Considering that such solutions will be more and more available in the future, we foresee the possibility to equip schools laboratories with immersive VR, or to directly exploit student's mobiles as cheap HMDs.

We evaluated the impact of immersive VR on high-school students motivation through a user test in two classes of the Filippo Figari High School in Sassari. The results show that the immersive VR increases the students' motivation in studying the lesson topic, in particular increasing their attention, satisfaction and the perceived relevance of the teaching material.

In future work, we aim to provide teachers with a proper authoring environment, a sort of Power Point for VR content, in order to better support them in the creation of the teaching material, and to evaluate both its usability and effectiveness with teachers. In addition, we would like to enhance the evaluation on two ways: on the one hand we would like to measure effect of the immersive VR visualization in a collaborative lesson setting, where all students are provided with HMDs; on the other hand it would be interesting to perform a long term study on both motivation and students' learning outcome in classes using immersive VR settings.

6. Acknowledgements

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