Interactive Historical Documentary in Virtual Reality

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***Abstract*—As digitization has transformed media and Virtual Reality (VR) and Augmented Reality (AR) have evolved from a research area to a commodity, digital media content creators are experimenting with VR digital storytelling. Most VR experiences are developed in a lean-back 360 immersive format with limited viewer interaction. This paper presents an innovative, first person Point of View (POV) highly interactive VR documentary titled *"The Revolution of 1897 in Crete"* aiming to enhance interactivity, eliminate character-related uncanny valley effects, promote non-obtrusive subtitle placement and techniques for familiarization with complicated VR controllers. Viewers are active participants through interactive tasks involving sound and music, supporting "doing" rather than just observing. We initially analyze interactive VR experiences to identify the specific characteristics of this new medium, composing a VR grammar. We evaluate task load and usability of the presented interactive and multimodal VR documentary. We propose design recommendations for creators of VR and AR media experiences in any context including cultural heritage.**

***Index Terms*—Virtual Reality, VR Storytelling, History and Culture, Multimodal**

I. Introduction

Storytelling is the act of sharing stories. These stories are told for entertainment, communication of information, or for education [6], [12], [14]. Storytelling is known to exist long before computers, cinemas and books, dating to 30000 years ago after the discovery of drawings in the caves. Storytelling is universal to the human experience [10]. As digitization has transformed media and Virtual Reality (VR) and Augmented Reality (AR) have evolved from research to commodity, digital media content creators are experimenting with VR storytelling. VR has proven to be a powerful tool for the realization of truthful experiences [7], [2]. VR Storytelling consists of VR cinema in the form of 360 video [13]. Interactive VR storytelling employes specialized controllers [9] transforming the viewers from passive spectators to active participants of the given play [6], both involving sound and music. However, VR is usually prone to usability issues inherent to the technology such as having to deal with the complex controllers for interaction as well as inhibiting motion sickness and movement restriction [1]. Storytelling in VR is facing challenges such as uncanny valley effects induced by near-realistic 3D characters and breaks of immersion by inadequate subtitles techniques. Such challenges are prominent in any context including cultural heritage.

Here, we present an innovative, first person Point of View (POV) interactive 6 Degrees of Freedom (DoF) VR documentary with the title *"The Revolution of 1897 in Crete"*, related to the historical events around the revolution of 1897 in Crete, Greece, aiming for independence against international forces. Our interactive VR documentary which includes sound and music as central elements aims to overcome shortcomings of past VR digital storytelling experiences resulting to design recommendations invaluable to VR developers of this new medium so that interactivity as well as fun is enhanced. Our specific contributions include:

- The customized design of 2D figure characters derived from archived photos and paintings of historical artefacts. These characters preserve realistic characteristics without causing uncanny valley effects as shown in a thorough evaluation.
- The development of static VR subtitles techniques attached to the character speaking, reducing motion sickness, enhancing the narrative and improving the communication of the story to the public.
- The implementation of a tutorial room which follows the same aesthetic as the main experience so that users are familiarized with complex VR controllers.
- The evaluation of the presented VR documentary revealed that VR can be an effective medium for digital narrative providing educational value.

II. Related Work

A. Uncanny valley effect

One of the most significant issues of the production of VR digital storytelling is that a large portion of digital experiences encounter the uncanny valley effect in relation to character design [17]. Uncanny valley is a perceptual mismatch caused by conflicting cues of a character's appearance, provoking negative emotions when characters are in almost human form [29]. The uncanny-valley hypothesis was established by German physician Ernst Anton Jentsch in his 1906 paper, "On the Psychology of the Uncanny" [28]. In his original article, Mori [29] suggested designers should avoid high levels of human likeness to maximize affinity between their products and reduce the uncanny valley effect. In our work, we employ cut-out figures from photos and show that, in this way, such effects are significantly reduced.

(a) (b) (c) (d)

Fig. 1: (a) Participant immersed in the VR Documentary (b) Approaching Akrotiri Cape (c) Renegades (d) Historical figure

B. Interactive Storytelling in VR

Storytelling comes in a wide variety of media forms, from very short stories to books, hand drawn animations to western feature-length motion pictures [6]. Interactive storytelling is a new form of telling stories enhanced with state of the art technology and social, educational and unique to each viewer features; the intersection of psychology, sociology, cognitive science, human factors, interface design and computer sciences [5]. Interactive VR storytelling is an experience where the viewers are active participants in the story, able to move around and carry out important tasks for the story to continue [22]. Conventional game-like storytelling is disrupted in the *Museum of Symmetry* to create a pleasant trip through nature and self [16]. The creators focused greatly on the design of earth, fire, wind and water landscapes, where vivacious 2D characters lived in a 3D playground. The interactivity of the viewers through small tasks advances the narrative.

VR interactive storytelling vividly documents historical events. The *Unknown Photographer* is a VR journey through hundreds of World War I photographs discovered in an abandoned barn in Morin Heights, Canada [18]. This documentary/fiction hybrid invites viewers to take a stroll through a museum, in a vivid dreamscape filled with stunning images accompanied by the photographer's thoughts. The 3D universe is composed of otherworldly structures, improbable architecture and sculptures as well as authentic historical photographs that seem both intangible and omnipresent. Viewers encounter engaging characters on their voyage through an allegorical world and are invited to face through images, the destruction of war in the present and past. Wearing an Oculus headset and guided by a narrator voicing the thoughts of the photographer, whose unseen presence permeates the experience, the viewer becomes immersed in a parallel reality where one's physical sensations and imagination are greatly heightened.

VR interactive storytelling also teleports viewers to space. The *Spheres* is a three chapter interactive VR journey uncovering the hidden songs of the cosmos [19]. This acclaimed experience premiered at Sundance and received the Grand Prize in VR at the Venice Film Festival. The viewer interacts with planets, stars and black holes, with the help of VR controllers, body movement in a room scale environment and voice, to discover sounds throughout the universe. Experiences such as the *BBC - Home - A VR Spacewalk* are inspired by NASA training programs involving British astronaut Tim Peake [20]. Astronauts embark on a spacewalk 250 miles above the Earth's surface. Viewers are tasked with making a repair on the outside of the International Space Station, before being confronted with a terrifying emergency situation. It is the first experience the BBC has released for VR.

VR interactive experiences play a significant role in communicating environmental issues. *Hold the World* created by SkyVR and Factory42 is a one-on-one VR audience with David Attenborough at the Natural History Museum in London, UK [17]. It transports the viewers to the 3D redesigned London's Natural History Museum, interacting with rare specimens from its world-famous collection virtually picking up, holding, enlarging and expanding them, giving them unparalleled access to some of the world's rarest natural history specimens. The *Hold The World* experience introduces great interactivity, however, it also falls short in terms of subtitles and apparent uncanny valley effects. The realistic photogrammetry approach followed in relation to scanning David Attenborough causes uncanny effects because of its robot-like, even if realistic form and lack of realistic cues such as realistic gaze, disrupting the narrative [29].

Interactive VR experiences as analyzed above testify the power of interactivity in VR in diverse application domains. Viewers are immersed in a story by acting, not just following events. Viewer-controlled freedom of movement and interaction affordances create a personalized experience of great impact. However, the lack of instructions and training in relation to the VR controllers is apparent as each experience maps specific actions differently to VR controllers' buttons. This caused frustration both to experienced and newcomers to VR digital storytelling and disrupted the perceptual continuity, emotional connection and general involvement with the content. The lack of subtitles which are necessary to non-English speaking viewers exclude the hearing impaired, limiting accessibility. Moreover, a large portion of digital experiences encounter the uncanny valley effect. Uncanny valley provokes negative emotions when characters are in almost human form. It is shown that character design based on video feed or highly realistic figures do not cause the uncanny valley effect [29]. We propose a solution to this issue by inserting low polygon 2D character design based on 2D cut-outs from archived photographs. We show that this strategy

does not cause uncanny valley effects.

C. Interactive VR Grammar

We form a VR grammar for VR storytelling and VR films based on common characteristics of the reviewed experiences. We will then follow the specified VR grammar for our own VR documentary.

VR Cinema aims to change the passive position of the viewer from lean-back, to a more active lean-forward position by allowing the viewer to look around freely, even when attending to a linear VR experience [15]. Because of this interaction capability between the viewer and the visual or multimodal content, viewers live their own interpretation of the experience which will never be the same for everyone. In a VR film, the viewer can have two perspectives taken into account in relation to the point-of-view (POV). A first-person perspective would describe them as part of the scene and a third-person perspective would describe them as observers [27]. Since both experiences are quite distinct and can have significant impact on how the experience plays out, the role of the viewer must be clearly outlined in the design of the narrative. In VR storytelling, the viewer can also freely roam around the 3D space and virtually grab 3D objects with the use of specialized controllers. As part of a strategy for viewer involvement and stimulation, a viewer-centric interactive approach should be used, taking into account both ”gamification” and ”rewarding” techniques [22]. The ”gamification” technique relies on the power of the audience over the frame and which angle they observe it. The ”rewarding” technique relies on the audience completing small tasks that are part of the story for it to continue. A variety of interaction types can influence the viewer experiences in terms of interest, immersion, fun, and ease of use [24].

Audiences accustomed to cinema films may passively enjoy VR cinema. VR creators can never be entirely certain where the audience will look at, therefore, viewers may not always focus where creators expect. Viewers fear that they will miss critical plot points due to the 360° spaces [25]. It is, therefore, crucial where the action and story elements are placed. The direction of the user's head determines the viewed frame. Consideration should be given to the distance between virtual objects and viewers. A closer distance may frighten viewers or make them engage more. [23] In contrast to a traditional cinema film, where every frame is carefully placed in the world, the audience in VR has complete control in the 360° environment. In the interactive narrative format, the viewer is the one ”walking through the narrative”, actively exploring and looking around [21]. By looking around, the viewer can miss critical details within the story and, thus, narrative and perceptual cues should be placed accordingly in space and time. Visual and spatial audio cues are common guiding users' attention originating from outside the viewers' POV [26]. VR experiences can benefit from accurate spatial audio implementation. VR offers a step outside the normal bounds of reality in unexpected and innovative ways.

III. Designing the Narrative

The process of planning and implementing the interactive VR documentary *The revolution of 1897 in Crete* was carried out in collaboration with the the National Research Foundation 'Eleftherios K. Venizelos' in Chania, Crete, Greece. The research foundation defines a national strategy for the systematic research and study of the era, work and life of Eleftherios Venizelos who is a Greek statesman and a prominent leader of the Greek national liberation movement. He is noted for his contribution to the expansion of Greece and promotion of liberal-democratic policies. The Foundation provided the archived materials (photographs, paintings, newspapers, journals) and historical insight. Here, we present the narrative structure and plot-points of the proposed VR documentary. We provide insight on how the narration was constructed, on the form of the characters to avoid uncanny valley effects, on the placement of subtitles so as not to obstruct the narrative and the placement of perceptual cues in relation to POVs and POIs of interest to enhance engagement.

A. The VR Documentary ”The Revolution of 1897 in Crete”

The *Revolution of 1987 in Crete* presents the last revolution of people from Crete against the Ottoman Empire and the international forces of that era which they eventually won marking the beginning of the independent Cretan state. This historical documentary highlights the beginning of Eleftherios K. Venizelos's career in diplomacy who will later become the most prominent Greek statesman. The documentary immerses the viewers [Fig. 1a] in the way of thinking and actions of Eleftherios Venizelos in three acts. After a fire that was set in the city of Chania by the Ottoman Empire, rebels in Chania wanted their freedom more than anything. A month later, the international forces arrived in Crete attacking the rebels, who stood their ground. E. Venizelos wrote a letter which stipulated that the rebels would keep their positions until everyone is killed from the shells of European warships, in order to gain their freedom. The letter was deliberately leaked to international newspapers, evoking emotional reactions about the war and revolution in Greece and in Europe. The idea of Christians, who wanted their freedom, being bombarded by Christian vessels, caused popular indignation. Throughout western Europe, sympathy for the cause of the Christians in Crete was manifested. The VR documentary was designed both with 2D and 3D computer graphics imagery and recorded spatial audio narrations and soundscapes to provoke engagement. Historical artifacts were reconstructed in 3D and carefully placed in the 3D environment for the viewers to explore and expand the narrative. The narrative communicates the emotions of Eleftherios K. Venizelos who is the protagonist and presents the hardship of war, promoting peace.

B. Narrative Structure and Plot-Points

The narrative of *The Revolution of 1987 in Crete* is to be experienced as an active participant from a first-person perspective on an Oculus VR HMD employing its controllers for interaction. Viewers initially enter a

tutorial room containing controller instructions. They are instructed to perform a minor task of transferring a 3D cube between specific locations. Viewers get familiarized with the controllers and are able to navigate around the 3D scene and grab objects. Specific tasks evolve the story. Virtually grabbing 3D historical artifacts involves the analog stick of the left controller used for movement and the bottom trigger button of both controllers for grabbing. For interacting with the UI menu, the upper button of the right controller was employed. The points-of-interest (POIs) where placed within the 3D scenes and the distance between the viewer and the POIs were taken into account for the placement of 3D artifacts in close proximity. This ensured that the viewer continuously interacted with the scene. When a POI had to be placed in far distance, it was scaled up in order to be easily seen by the audience and attract their attention. Finally, special frames responsible for the transition from one scene to another were inserted and an add-on layer of particle effects was applied in order to be easily tracked by the viewers. A combination of visual and audio cues is more effective at guiding viewers' attention than only visual cues. We implemented spatial bird sounds and nature soundscapes acting as navigation clues. The closer the viewer moves towards a POI, the higher the sound volume and vice versa. Three different 3D scenes were created, where the documentary action takes place.

Scene 1 - Eleftherios K. Venizelos's office. Here, viewers will see the protagonist prompting them to go back in time and experience what happened in the battle of Akrotiri. The audience can interact with archived old, readable newspapers of that time, gaining historical knowledge. On the right of the office, they will find an old gramophone and next to it vinyl disks. By grabbing a disk and placing it on the gramophone, it will start playing music of that period creating a relaxed soundscape. The playing disk on the gramophone is placed at 90 degrees angle for the viewers to grab. The office scene is filled with frames containing archived paintings from E. Venizelos's house. Viewers can virtually grab and examine in close range the 3D replica objects located on the desk as well as open the drawers of the E. Venizelos's office and find objects such an an old watch replica, the constitution of Crete, an old pen, an ink cartridge and an old key.

Fig. 2: Scene 2 - Akrotiri Cape

Scene 2 - Akrotiri Cape. In this scene, the viewers find themselves on a wooden boat in the foggy and waviness Aegean sea [Fig. 1b] travelling to Crete [Fig. 2]. A local from Crete narrates the history of the period. The viewers travel through an intense soundscape of rainy storm and explosions. When the wooden boat comes closer to Crete, Greece the sun rises and the storm eases. The narrator prompts the viewers to jump into the sea and find E. Venizelos, retrieve a letter he wrote and later give it to the admirals of the Great Forces. The so-called Great Forces, named as such after the Greek revolution of 1821, was the alliance of the states of Britain, France, Austria, Russia and Italy. While the viewers do this task, they can also search for historical characters and get additional insight to the story. In their search for E. Venizelos, viewers can also find historical old pitcher artefacts which were stolen during the war and replicas of the guns used in the revolution. Twenty-two months later, Crete was liberated and declared an autonomous state.

Fig. 3: Scene 3 - Chania

Scene 3 - Chania. [Fig. 3] Here, the viewers travel back in time and get to experience the burning city of Chania in January 1897 which is the actual event that led to the revolution. The viewers fall from the sky through the clouds of fire, only possible without earth gravity in VR, while intense feelings are evoked. As viewers land on the ground, a narration starts explaining the situation and giving insightful details of that historical circumstance. Viewers are free to roam in a closed borders city environment full of randomly generated explosions. In that environment, scanned newspapers' front pages and images from the destruction of Chania are seen. The primary goal of this scene is for the viewers to navigate through the obscure and full of flames town of Chania so that they can be saved. The transition from one scene to another happen when the viewers pass through specific frames placed in the 3D environment. When viewers navigate through these special frames, they enter a screen room while waiting for the next scene to load. Viewers can only interact and pass through the special frames when they have completed the designated tasks of each corresponding scene. The end credits follow the traditional movement of cinema credits bottom-up. They were spatially placed in black void so that the viewer can see them all the way down and all the way up.

C. Narration and Perceptual Cues

In order to create the main path of the experience, we worked on the screenplay with the National Research Foundation 'Eleftherios K. Venizelos'. Most of the narrations have been derived from archived historical journals. The narrations have been reworked in order to bring out the stronger emotional elements of the archived texts and guide the viewer through the 3D generated scenes. For life-like narration, two narrations were attached to most of the characters[Fig. 1c].

(a) (b) (c)

Fig. 4: (a) scanned archived photo, (b) cut and enhanced figures, (c) 2D figures in 3D VR

That capability consisted of an extra interaction element for the viewers which enhanced engagement instead of the same narration being repeated. In order to implement the narration, we created trigger events around a specific radius near the characters. The narration starts when the viewers step close to the characters, stops when the viewers move away and starts again if they move back. The narrations were recorded using first-order Ambisonics surround audio over headphones. Engagement is increased based on the fidelity and authenticity of the spatial sound reproduction [8], [30]. Original visual cues were derived from historical archives, paintings and photographs from archived newspapers so that the story's narrative is enriched. The letters, European newspaper front pages and character figures enhance the authenticity of the story and emotional connection of the viewers with the characters. The archived context was digitized. The digital material was later worked into a raster graphics editor in order to recreate parts that were damaged.

IV. Implementation

The interactive VR documentary presented in this paper was developed in Unity 3D, displayed on an Oculus Rift HMD, optimized for a middle-end computer so it could be more accessible by a larger audience. The computer hardware specifications were based on an Intel(R) Core(TM) i7-7700 CPU @ 3.60GHz, two 4 GBytes DDR4 RAM and a NVIDIA GeForce GTX 1050 Ti GPU.

A. Autonomous and Non-Autonomous Agents

Two types of agents were implemented; autonomous and non-autonomous. An autonomous agent is a system situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to effect what it senses in the future [32]. An autonomous agent can be characterised as an interactive character that could behave in different ways based on the audience behaviour. For a truly interactive VR experience, there is need for interactive characters [31]. In the Scene 2 - Akrotiri Cape, as the viewer arrives to Crete island with a small wooden boat, the narrator says that the boat cannot approach the island any closer. The narrator prompts people on the boat to jump in the water and find E. Venizelos. When viewers virtually jump in the water, they find themselves submerged in a lively reef. The marine life underwater are represented by autonomous agents [33]. Every time the scene loads, a system developed is responsible for the exact quantity of each fish species to be spawned in the sea. An area was defined and invisible points where the fish are able to move to and from. The fish agents can sense the presence of the viewer and also of the paths other fish are on, change direction to a different point, where no other fish is moving from or to, when the viewer tries to come to close proximity. Moreover, as the main characters and their stories are greatly responsible for viewers' engagement, a near-life but not of high fidelity implementation of character animation and modelling would lead to uncanny effects, e.g. viewers' negative reactions. We propose an innovative approach of working with historical figures derived from archived photographs and paintings [Fig. 4a]. We initially decided upon which historical characters would populate our documentary and these were digitized. Through a raster graphics editor damaged material were enhanced and the outline of the characters was cropped [Fig. 4b]. We, them, imported the outline of the characters to a 3D software where we add a cap to the outline, in order not to have a flat appearance. Finally, we imported our characters in the 3D scenes [Fig. 4c].

B. Subtitles

We aimed for a multilingual VR documentary and we created a subtitle system in order to handle the translated narrations. We experimented with two types of subtitles, e.g. static subtitles spatially anchored next to the speaking character which were preferred [Fig. 1d] and static subtitles spatially anchored to the viewer POV causing motion sickness. The subtitles attached to the character speaking enhanced engagement and induced less motion sickness. We implemented a dynamic subtitles system to respond to the current narration. Each character holds at least two narrations and depending to which one is told each time, the subtitle system will enable the text accordingly. The subtitles were placed as static near the historical figure speaker for character identification. The subtitles mechanic gets triggered by the narration mechanic. The subtitles should be easily readable, supporting the flow of the story; indicating who is speaking. The subtitles should enhance the viewer's understanding of the story and not disrupt experience because of eye strain or motion sickness. We implemented two models for testing; flowing subtitles fixed to the rotation of the viewer and fixed subtitles next to the

speaker model [11]. According to our pilot studies, the fixed subtitles felt more natural to the viewers and enhanced the flow of the story in contrast to the flowing subtitles.

C. Optimisation

The challenging performance issues of VR are CPU and GPU issues. The CPU is responsible for the graphic simulations such as the low-level water and particle simulation during gameplay, the states' management and the generation of the scene to be rendered. The GPU is responsible for sampling our textures and shading the generated meshes. Performance issues were apparent from high polygon count making real-time rendering challenging. To mitigate the GPU, instancing was implemented to reduce the number of draw calls used per scene. High detailed assets were imported in Blender 3D in order to reduce their triangle count, while still having the AAA look. Lastly, occlusion culling, a process which prevents Unity from performing rendering calculations for GameObjects that are completely hidden from view (occluded) by other GameObjects, was applied to each scene.

V. Experiment and Evaluation

We conducted a user evaluation to assess usability and workload, exploring uncanny valley effects, subtitle placement, diverse seating or standing positions for users experienced in VR or not, free or locked rotation between positions of 30 deg. viewing angle and motion sickness.

A. Participants

There were 16 participants, 11 male and 5 female, 50% enrolled students from computer engineering, 32% professionals from media industry and 18% from other fields of research such as architects. 75% had previously used VR.

B. Apparatus

The apparatus was a high-end computer which consisted of a Intel(R) Core(TM) I9-10900 CPU @ 2.80GHZ, two 16 GBytes DDR4 RAM, a MSI GeForce RTX 3070 8GB Gaming Z Trio GPU and an Oculus Rift S HMD. An executable file ran through Windows OS on an Oculus VR HMD.

C. Methodology

Participants with no or little experience were seated, instructed to rotate their chairs to get oriented. Participants with VR experience stood, instructed to move within the virtual bounds. Participants were provided with hygiene masks and the Oculus HMD, holding the VR controllers. Upon completing the VR documentary, the participants were interviewed with regards to their experience and their understanding of the story. They filled out a standard usability questionnaire related to Mixed Reality experiences assessing efficiency in: Learnability, Efficiency, Memorability, Accuracy, Satisfaction, Intuitiveness and Fun [36], [37]. Moreover, the NASA TLX survey for perceived workload was administered [38]. The NASA TLX assesses perceived performance effectiveness on: Mental demand Physical demand, Temporal demand, Performance, Effort and Frustration. These were graded on a 5-point Likert scale (1= very low, 3= neutral, 5= very high).

VI. Results

A. Data Analysis

The average time it took each participant to go through the interactive documentary was 19.3 minutes. Participants discovered most of the content that was included in the experience. Participants reported an average 2.87 (SD 1,36) experience in VR. Processing the answers from the Mixed Reality questionnaire [Fig. 6], participants reported that they had been helped with the Tutorial Room scene (avg 4.67, SD 0.59), obtaining an ease of interaction in the VE (avg 4.24, SD 0.75) and ease of movement in the VE (avg 4.43, SD 0.6). The overall comfort of the VR HMDs was pleasant (avg 4, SD 0.61) as well as the overall physical comfort (avg 4.37, SD 0.78). Participants experienced sense of dizziness (avg 2.5, SD 1.22), with 5 "being all the time". Certain participants experienced a heighten sense of dizziness. It was noted that larger perceived dizziness was associated with experiencing the interactive documentary either standing or/and with free rotation. The reported enjoyment was very high (avg 4.75, SD 0.56) and the majority of the participants would like to experience another VR film in the future (avg 4.68, SD 0.84).

Participants reported a high sense of being in the VE (avg 4.37,SD 0.6) [Fig. 5]. They navigated easily through the 3D environment (avg 4.63,SD 0.48) while having a sense of orientation in the virtual world (avg 4.58, SD 0.7) and did not feel lost (avg 4.25, SD 0.56). Meanwhile, they felt inclusion in the world (avg 4.43, SD 0.6) and had a great Understanding of where everything was (avg 4.68, 0.46). Participants indicated that the experience invites exploration (avg 4.5, SD 0.93) and introspection (avg 4.12, SD 1). Participated had ease of getting where they wanted to go (avg 4.37, SD 0.7), were greatly engaged by the experience (avg 4.81, SD 0.52) and were very satisfied with the historical context presented (avg 4.75, SD 0.56). Most importantly, participants did not experience aversion to the 2D characters (avg 1.87, SD 1.05), therefore, there were no apparent uncanny valley effects based on our technique utilizing cut-outs from photographs and 2D character design. The participants who experienced the documentary in English (50%) indicated that the subtitles were comfortable (avg. 4.75, SD 0.43) and their feeling of inclusion was high (avg. 4.63, SD 0.48). The participants enjoyed the experience (avg. 4.63, SD 0.7), had a great understanding of where everything was in the world (avg. 4.75, SD 0.43) and were very satisfied with the historical context (4.62, SD 0.69). The majority of the participants who experienced the documentary with English subtitles had low sense of dizziness (avg. 2.37, SD 1.4). High values of dizziness come from participants who experienced the documentary standing with free rotation. A short discussion took place with each participants after they finished the VR documentary.

B. User Experience

Educational VR experiences focusing on cultural heritage are heavily created in 360-video or 2D animation format. Participants with previous VR experience as such were intrigued

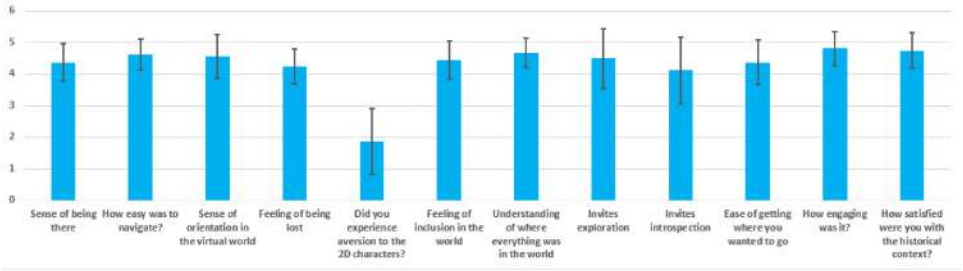

Fig. 5: Experience related avg. answers with standard deviation

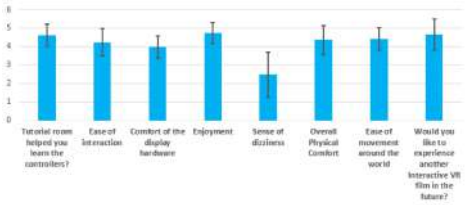

Fig. 6: Hardware related avg. answers with standard deviation

with the interactivity of our interactive experience. Participants continuously felt active participants through interactive tasks, involved in "doing" rather than just observing, increasing the emotional connection to the characters and the story. The self-reported emotional outcome of the participants through the first two scenes was happiness, relaxation, amusement and excitement. The emotional outcome of the participants through the third scene was fear, anxiety and sadness.

VII. Discussion

Participants with no experience in VR reported they did not need to ask questions in relation to how the controllers worked because of the initial tutorial and guidance. Inexperienced VR participants who selected to experience the documentary standing with free rotation capability showed high levels of dizziness. Highly experienced users who used either standing or free rotation options did not report dizziness and they expressed they fully enjoyed it [35]. Highly experienced users were happy to see the inclusion of the option of free rotation, as most experiences do not included it. Participants expressed enjoyment navigating the underwater reef. Adventurous participants went deeper into the sea finding a 3D reconstructed shipwreck. Participants enthusiastically explored the deep waters scene outside the main path-line and discovered hidden historical context and a shipwreck. Certain participants reported that visual cues would have been useful to indicate interactable objects such as using a soft highlight on the objects to be interacted with, when they came close to them. Participants felt comfortable with the cut black and white 2D figures approach. The figures gave them the feeling of co-existing with the historical figures. They did not experience aversion. 2 participants from the media industry reported that they would prefer them colorized and semi-transparent. Half of the participants experienced the VR documentary with English subtitles. Their placement was ideal and comfortable for them to read. Subtitles gave emphasis to the character speaking and they enhanced the narration in the Greek language better than dubbing. Participants were not aware of the historical events and the war, but knew the protagonist, e.g., Eleftherios Venizelos. Participants had introspection during the documentary and felt involved with the story and the sense of war. Participants had a complete understanding of the story. Participants would prefer wireless HMDs, as the cable entangled in the chair when seated. Participants wearing glasses could not wear the HMD comfortably which is an inherent issue of the technology.

VIII. Design Guidelines

Narrative planning and character dialogues should be the first priority in the design steps. Character dialogues and interactable objects can be marked with alphabet letters or other characteristic for easy recognition. A top-down map of each scene is highly proposed to be drawn on paper and the objects for interaction placed clearly. With this hand drawn map, designers can sketch the desirable paths they would like viewers to follow. Interactable characters and objects should be placed in close proximity from one another. When they are placed further away, they can act as hidden content and enhance the will for exploration. A combination of visual and audio/music cues would guide viewers' attention, since spatial audio cues can originate from outside the viewers' POV. An implementation of autonomous characters increases viewer engagement. Characters should be able to speak more than one assigned narration or dialogue according to the narrative. Static subtitles can be placed next to the speaking characters. For a low-budget production, the use of 2D characters can overcome uncanny valley effects and is preferred to near-life, cartoonish or other low-fidelity character design. The use of a tutorial room or an entry mission which familiarize viewers with the VR controllers is highly recommended.

IX. Conclusion and Future Work

"The Revolution of 1897 in Crete" is an innovative VR documentary including visuals, sound design and music. Viewers step outside of the normal bounds of reality and revisit a part of history of Crete, Greece, in a totally new and unexpected way. Participants offered positive and sometimes enthusiastic feedback which strengthens the premise that interactive VR films are here to stay. The story could be enriched with

an AI-story generator automatically generating content and narration according to viewers' progression and interests. Scenes and sound/music clips could be added to the experience to enrich the story line and time frame. VR collaborative environments could also enhance the collective understanding by co-experiencing a story and even co-operating in order to progress building a common memory for the participants.

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