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Original Study

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The Contribution of 'Total Environment' Reconstructions in Interpreting Ancient Greek Experience of Ritual Spaces

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Abstract: The temple of Epikourean Apollo in Bassae has long been suspected to have been constructed with astronomical considerations, aimed at influencing ancient religious experience. The study presented here involves the use of Virtual Reality software to reconstruct the temple in its original position and orientation, combined with an accurate reconstruction of the sun's position during the Classical period. The aim is to test the hypothesis of deliberate solar considerations associated with the temple's east entrance. The reconstruction also discusses the application of Virtual Reality Models (VRM) and their potential impact on understanding ancient spatial movement and memory, emotionality and cognition. In addition, it explores the possibility of ancient natural light manipulation in enhancing experience of religious architecture. This paper not only presents the first VRM of Apollo's temple, but also a model with an accurate reconstruction of the sun's position at specific moments in the year. The importance of such reconstructions in understanding religious experience is exemplified. A great deal is revealed about the proposed solar effect in relation to human observation, and the connotations of such an effect in specific religious contexts. This study could facilitate discussion on the contribution of digital technology in understanding ancient Greek ritual experience.

Keywords: Virtual Reality Modelling, Apollo Epikourios Bassae, Greek religion, ancient astronomy, light in archaeology

1 Introduction

We tend to investigate ancient sites from above. Our analyses of ancient landscapes and ritual spaces very often confine themselves in the boundaries of bi-dimensional plans, photographs and maps. Even in those cases where 3D reconstructions are generated, or other forms of digital technology are employed such as photogrammetry, GIS, or even Virtual Reality Modelling (VRM), our reconstructions consistently miss out one third of the visible natural environment, which in our daily lives is ever present: the sky. In modern city-dwelling, tall skylines obstruct visibility of the sky; but who could disagree that the season, or time in the day or night is exclusively responsible for shaping our experience of natural places, even architecture, in the absence of artificial light? The impact of the skyscape was even more palpable in ancient communities, whose existence relied solely on being able to determine the precise time in the year agricultural practices

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had to be performed or on knowledge of the night-sky for seafaring. Observing the heavens permeated ancient daily life. In Classical cultures this is easily verified by the presence of sundials and *parapegmata* in ancient Agoras and sanctuaries (e.g. Athenian Agora, sanctuary of Apollo at Klaros, Miletos, etc.). Let us not forget also ancient open-air nocturnal rituals, performed around an altar, engulfed by the entire carpet of mythical celestial figures, seemingly rotating around these religious spaces.

The concept of 'total environment' analysis contains much more than structures and their landscapes. It is also time-specific. It integrates temporal elements such as the time of day and night and month during which sites were visited for the performance of rituals. Thus, total environment reconstructions include faithful and accurate reconstructions of the night-sky and the position of the sun and moon.

The application of 3D technology has become widespread in archaeology. A large number of highly informative studies have reshaped our understanding of ancient space and architecture through high-resolution reality-based digital models. These virtual representations facilitate diachronic analysis, by enabling us to *see*, what until very recently could only be imagined through drawings or narratives. We still have a fair way to cover in relation to the creation of realistic environments. This need has been targeted by more recent research, which now employs a number of methods and techniques, such as high-resolution rendering, laser scanning, photogrammetry, kinaesthesia, etc. (e.g. Dylla et al., 2008; Guidi et al., 2005; Guidi et al., 2014; Wallace et al., 2019). All this work is leading us beyond 3D technology and into VRM, which can facilitate a more complete experience and greatly improved immersivity.

Regardless of whether approaches produce 3D or VR models, however, we notice a general lack of attention in the recreation of accurate sky reconstructions at specific times in the year, day or night. Naturally, this reflects the aims of these studies, which do not concern themselves with specific, solar, stellar or lunar effects, and aim instead to recreate and analyse spaces without accounting for the physical properties of light. Partly, this is also due to software limitations, which generally provides only 'common lighting solutions' (Papadopoulos & Earl, 2009, pp. 58). It is worth noting, however, that it is unlikely that human perception of these spaces was not influenced by the time of the day or season. Vision relies equally on perception and cognition. Although the two cannot be delineated, as much feedback and cross-talk occurs between them, the direction of gaze is undoubtedly affected by these cognitive processes, which can also guide perception and attention (Sundstedt et al., 2013, p. 547). Thankfully, as we will see later, some recent research has concerned itself with the importance of light in digital reconstructions. The present study aims to contribute an example of the level of impact such reconstructions can have on our understanding of space, movement and experience.

The use of the term 'reconstruction' has been questioned for its accuracy in describing these digital creations, on grounds of elements of modern interpretations and decision making necessary in archaeological reconstructions (Clark, 2010; Papadopoulos & Kefalaki, 2010, p. 46; Tilley, 1994, p. 73–74). However, the application of digital technology, at least in this paper, remains at heart 'reconstructive', as computer graphics and high-resolution rendering is employed at the service of virtually generating past worlds. In this paper 'reconstruction' is employed in a conventional sense, acknowledging that what is created is not an attempt to 'revive the past' – such an attempt is widely acknowledged as futile – but instead, to recreate specific past temporal conditions (i.e. sunrises).

Of course, it is also acknowledged that this attempt is not without its limitations and difficulties. For the discussed reconstruction, these pertain mostly to the way the chosen digital tool diffuses sunlight. Three dimensional reconstructions have been more advanced in this respect. Recent research has demonstrated the importance of accurate light simulations, capable of reacting according to changes of natural light at different times in the day, the diffusion of artificial light, as well as in relation to the reflective properties of objects contained within structures, or of different building materials (Callet et al., 2010; Chalmers, 2002; Devlin & Chalmers 2001; Devlin et al., 2003; Happa et al., 2009; Masuda et al., 2006). Much recent work has focused on the creation of realistic visualisations, with some impressive results. Unfortunately, it has not been possible to produce such realistic light diffusions in the software selected for the current study. Despite this limitation though, the analysis provides exciting results in establishing the movement of direct sunlight in the temple's interior, despite its non-realistic diffusion. It is because of this limitation that a lighting analysis discussing the light/shadow effects of the reconstructed moments is not presented here.

In archaeology, the advantage of virtual environments over static 3D reconstructions is that they facilitate a better experience of environment. For the present project, we have one more added advantage: the VRM allows us to witness the path of sunlight in the temple's interior and its effect. We can better discern the conditions which shaped ancient experience of religious spaces, so that they, in turn, may help us identify the ways in which darkness, and illumination may have assisted in intensifying ritual experience. For the first time, a VRM has been constructed for the temple of Apollo Epikourios in Bassae. More importantly, a model which includes also an accurate reconstruction of the sun's position at specific moments in the year, long suspected to have had an impact on ancient experience of the temple. The study which follows presents an analysis of one of the most intriguing ancient Greek temples, an excellent candidate for demonstrating the value of digital technology in the service of Archaeology and, simultaneously, an excellent candidate for demonstrating the importance of total environment reconstructions to our understanding of religious experience.

2 The Temple of Apollo at Bassae

The temple of Apollo Epikourios was covered with a canopy in 1980, for protection against extreme weather conditions (causing its rapid deterioration) and to facilitate restoration. It has not been possible to study the structure within its environment since. It seems ironic then that this is the only ancient Greek temple whose positioning has received so much attention, on suspicions of solar links related to its orientation. The protective canopy aside, the preservation of the extant Classical temple of Apollo does not allow us to experience the illuminating effect of the rising sun in the temple's interior, long suspected to have been the intention behind its orientation and its east entrance.

The sanctuary of Apollo is situated on a rocky peak of the sacred Arkadian mountains in the southern slope of Mount Kotilion, at 1130m elevation and less than 1km away from ancient Phigaleia, the closest ancient city. The temple, despite being located on a high mountain peak, does not occupy a prominent position in its surrounding landscape. The extant temple, one of the most exquisite ancient Greek temples, dates to the Classical period. But the temple has attracted attention also because of the implications of the positioning of its eastern doorway. Frederick Cooper (1968) has argued that a deliberately orchestrated illuminating effect was created when, in midsummer, the rays of the rising sun would enter the temple's *adyton* and would shine on the cult statue placed probably there. Conversely, according to Madeleine Jost, the cult statue is more likely to have been placed in the *sekos* instead (Jost, 1985, p. 95). Written sources mention the presence of a bronze statue of Apollo, which was moved to the Agora of Megalopolis in later times (Pausanias 8.30.3–4), but no traces of a cult statue base have been identified in the temple's interior, rendering its position within the temple unknowable. Furthermore, Cooper found evidence of the southern door leaf of the east entrance being permanently fixed into shut position by a single backing block placed behind the door valve (Cooper, 1968, pp. 106–107). The purpose of this was argued to have been a deliberate intention to only allow a small sliver of sunbeam to enter the *adyton* for the desired illumination effect. Quite possibly, but in order for this effect to be appreciated, the feast day had to take place around midsummer. And if we follow Cooper's argument on the deliberately orchestrated admission of a small sliver of sunbeam entering the *adyton* as the result of only the narrower door valve (north) being open, then the temporal window for observing this effect becomes even narrower. Given the several Apollo festivities celebrated close to this time in the year throughout Greece (e.g. in Athens, Delphi, Delos), a festival at this time of year does not seem farfetched, but the precise time of the festival to Apollo in Bassae cannot be fixed with any degree of certainty. We have simply no idea when it took place.

Many of Apollo's *epikleses* associate him with the sun (e.g. Phoebos, Lykeios, Aigletes (god of light or sun with a temple in the Aegean island of Anafi), Apollo Eos (of the Dawn)). In literature, he is widely identified with Helios (Sun) and a number of cults link the two divinities (e.g. in Rhodes, Athens, and the Boeotian Daphnephoria) (Euripides, *Phaethon* 224–6; Plato, *Laws* 946c; Plutarch, *De Defectu Oraculorum 413c*; Plutarch, *De Pythiae Oraculis 400c-d*; Plutarch, *De E apud Delphos* 393c–d; *Orphicorum Fragmenta* 413.10, 536.2–4 (cf. Bernabé, 2005, pp. 109, 110); Proklos, *On the Hieratic Art* 150.10–5; Biliç, 2012, pp. 513–

515; Hurwit, 2017, p. 540). In addition, the sun's fundamental importance in human existence stands as testimony to Apollo's cosmic significance. His importance in the Greek pantheon requires little asserting, but the god's cosmic role is also palpable in being viewed as the god of music, which also carried cosmological significance though the sixth century BCE Pythagorean ideas of the music of the spheres. Plato, in particular, explains how Apollo directs celestial and musical harmony (Plato, *Cratylos* 405c–d). Apollo's association with the cosmos is of particular relevance to this study, through his connection with light. Such an example is the belief of Apollo residing in the land of the Hyperboreans during the winter months, the land with days of extreme length and very short nights, thus better suited to the god of light (Pliny the Elder, *Natural History* 4.88ff; Fontenrose, 1959, pp. 382; for a more detailed discussion see Boutsikas, in press).

The discovery of a tortoiseshell lyre (one of two ever discovered in sanctuaries, the second also dedicated to Apollo at Mon Repos in Kerkyra) ca. 10m north of the temple's NW corner finds correspondence to the temple's decoration: one of the north porch metopes (metope P4) depicts Apollo holding a lyre met by a male figure pouring a libation (see Madigan, 1992, p. 19). This has been taken as evidence of Apollo in Bassae being related to Apollo Kitharoidos (Apollo holding a lyre) and Apollo Lykeios, who also carries a lyre (Cooper, 1996, p. 69). What is even more interesting in this depiction is that Apollo's attire is identified as characteristic of those of northerners, leading to the conclusion of a depiction of Apollo having returned from the Hyperboreans. The entire scene, comprised of six metopes, seems to depict the moment of the god's return from the land of the far north (Madigan, 1992, pp. 18–22, 27), a scene which finds parallels in the description of his return in the *Homeric Hymn to Apollo*. As the temple faces north, the metopes depicting the scene of Apollo's return mark the direction from where the god would have arrived (Madigan, 1992, p. 27). The idea of deliberately positioning the temple's architectural elements to the direction of relevant topography, finds support also in the southern metopes (above the temple's *opisthodomos*), which depict the rape of the Leukippidai, marking also the direction to the south towards the Neda Valley, the area where this event was believed to have occurred (Madigan, 1992, pp. 13–14).

A number of factors prevent us from observing the effect caused by the rising sun in the temple's interior. Firstly, the temple's current state of preservation is missing key architectural elements. The eastern doorway does not survive intact. Furthermore, the nature of foundations used for the temple of Apollo has caused considerable movement of the structure above ground level. In order to protect the temple from seismic activity, a layer of clay and sand was added between the temple's foundations and the bedrock at the time of its construction (Jenkins, 2006, p. 134). Weathering of these materials has resulted in considerable movement of the temple's paving, which, in turn, has caused the columns to tilt (Jenkins, 2006, p. 134; Psycharis et al., 2000). This effect is evident in the columns outside the eastern doorway, which Copper measured to tilt 0.07° to the south and 0.80° to the west (1996: Pl 10). This shift would produce a different light effect. Since the installation of the canopy around the temple in Bassae, it has not been possible to obtain photographs, or actual observations relating to light effects or landscape. In addition, the sun's position has moved since the fifth century BCE. Thus the use of a digital reconstruction is the only available avenue in determining, rather than speculating, the light effect of the sunrise inside the temple.

During the ascend to the temple, the eastern horizon was revealed at the southern end of the external colonnade and the temple's *adyton*. A narrow passageway along temple's east wall (Kelly, 1995, pp. 263) indicates that visitors walked along the temple's eastern exterior. Open horizon views are visible towards the NE–S (Figure 1). A survey of the Classical temple's orientation and horizon shows that the east entrance was indeed oriented to sunrise one week before the spring equinox (declination -3°) at the time of the temple's construction and for centuries later (Boutsikas, in press). During this time, the rising sun aligned to the temple's side entrance on the equivalent of our 18 March. The change caused by precession resulted to a slight shift in the sun's position by the first century CE, so by this time the sun aligned with the orientation of the entrance on 15 March. The equinoxes mark the time when the days become longer or shorter, an appropriate timing for the god of light.

Archaeologically, it is certain that the orientation of the temple was fixed from as early as the Archaic period. The architectural design of the Classical temple and its Archaic predecessor (ca. sixth century BCE), located only 10m further south, have a number of similarities (Figure 2). The orientation of the Classical temple is slightly shifted towards the east compared to the Archaic (Figure 2). The layout and size of the *sekos* and *adyton* is almost identical in both temples. This effort to imitate the plan of the earlier temple is also apparent in the placement of the Classical temple's floor level as close in height as the north end of the Archaic floor level, despite the effort required to cut into the natural rock in order to achieve this. The exact dimensions of the Archaic east doorway are not known, but its placement corresponds to that of the Classical temple. The doorway is estimated to have been narrower than the preserved 2.5m wide gap and was certainly off centre of the marked *adyton* space (Figure 2) (Kelly, 1995, pp. 234, 238, 241). The Archaic *adyton*'s ground plan is also marked by an unusually thick northern wall, separating it from the *sekos*. This thickness is seen as necessary in order to retain the levelling fill used in the temple's *sekos*, but conclusive evidence as to whether the wall divided the two areas of the Archaic structure completely, is absent (Kelly, 1995, pp. 242–243). The small discrepancy in the size of the two *adyta* has been interpreted as enigmatic unless connected to the light effect at sunrise (Kelly, 1995, pp. 243).

Figure 1. Bassae NE–E horizon of Classical temple. (Photo by E. Boutsikas).

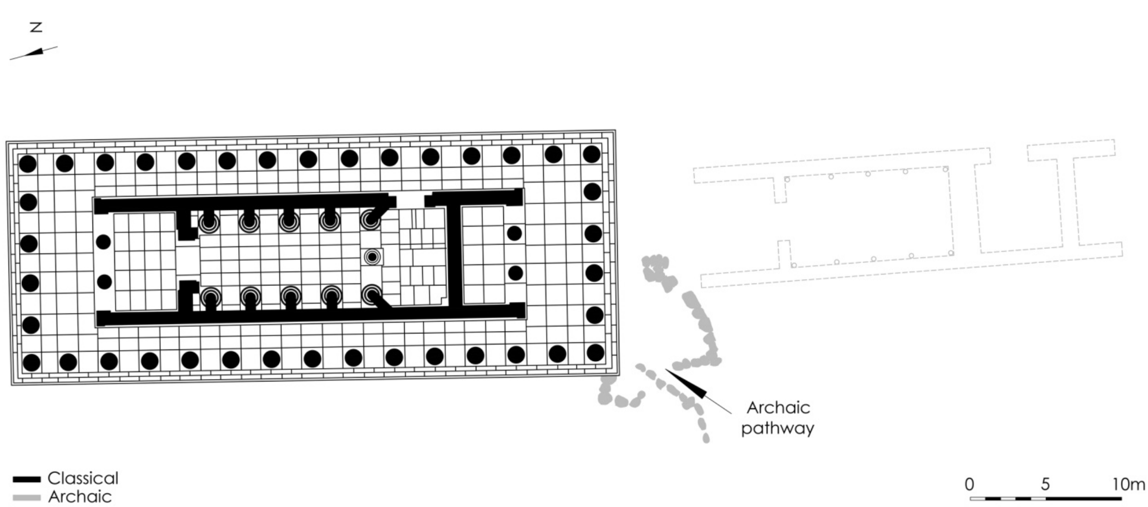

Figure 2. Ground plans of the Archaic and Classical temples of Apollo in Bassae (adapted after Kelly, 1995 by Socratis Tsacos).

The floor levels between the structures are quite different. The Archaic *adyton* floor level drops by ca. 1.4m (Kelly, 1995, pp. 248 and 235–236) compared to the temple's north end. This resulted in a sunken *adyton* and *opisthodomos* compared to the *sekos* and *pronaos*. This change in floor levels between the *sekos* and the *adyton* is not reflected in the Classical temple, which maintains the same floor level throughout its interior, but differentiates between the spaces through the use of different grid patterns in the paving for the floor (Figure 2). The most striking of these patterns is the Classical *adyton*'s, whose paving does not follow a grid. The irregularity in the grid starts at the *stylobate* slabs used under the oblique columns and the Corinthian column, which separate the *sekos* from the *adyton*. Dinsmoor's idea that this pattern is concentric around an object placed on the largest slab of stone found against the centre of the south wall and directly behind the Corinthian column (Dinsmoor, 1933, p. 213) could indeed justify the size of the slab, but this positioning would make this object invisible from any position along the central axis of the *sekos*, as the Corinthian column stands in the line of sight. The viewer would have to be squeezed against one of the side columns in order to see this object. Cooper further suggests that the entire focus of the Classical temple's arrangement was centred around the illumination of the SW corner paving block (Figure 3). He argues also that this block was used as the orientation setting cornerstone and the cult statue of Apollo was placed on the same axis (Cooper, 1968, pp. 106, 108–109). As discussed previously, we lack supporting evidence on the position of the cult statue. Furthermore, the VRM results presented below reveal that the SW corner was not illuminated by the sun, a factor which weakens Cooper's argument.

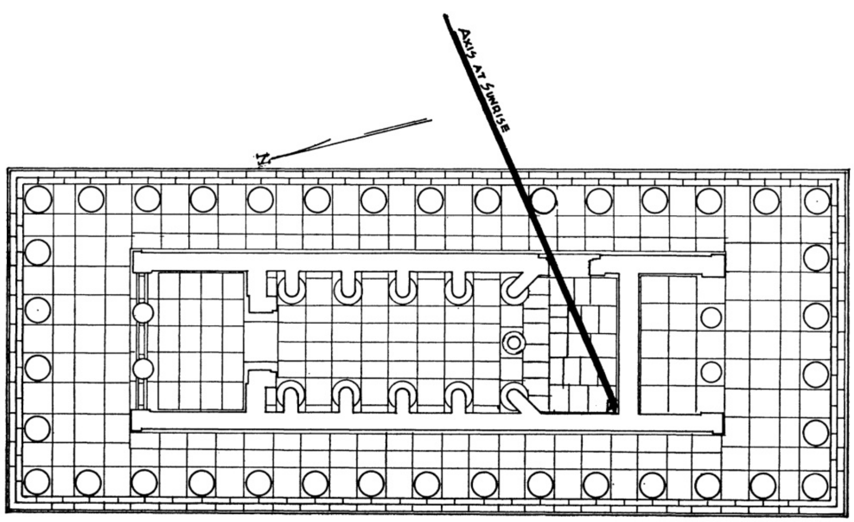

Figure 3. Cooper's reconstruction of the angle of the light beam entering the *adyton* (after Copper, 1968, p. 104).

3 Digital Reconstruction: Background and Methods

The first virtual reconstructions in archaeology go as far back as the 90s. These initial attempts produced void architectural spaces. No social or other implications were considered; their aim was to simply recreate the chosen structures and spaces (Forte, 2014, p. 115). Since then, the importance of digital technology in the evolution of archaeology has blossomed, as easily revealed in the countless applications of 3D and VR technology in archaeological research. The present paper concerns itself with a reconstruction, in which (natural) light plays a decisive role. The study of light has concerned Greek archaeology in the past two decades, with a focus, until recently, on the context of religious practice and belief (e.g. Antonakaki, 2007; Christopoulos et al., 2010; Nesbitt, 2012; Parisinou, 2000). More recent work employing advanced digital technology has investigated the role of light in ancient Greek prehistoric domestic and funerary contexts (e.g. Papadopoulos & Earl, 2014; Papadopoulos et al., 2015), with a few very welcome approaches of accurate total environment reconstructions (i.e. including correct astronomical data) (e.g. Papadopoulos & Earl, 2009; Sundstedt, et al., 2004). As also acknowledged by these authors, this is particularly important when investigations aim at how a site or structure appeared, or was experienced. This is true both for natural as well as artificial light. These studies exemplify, the significance of luminosity, darkness and shadow in human perception, by addressing questions such as, how far did sunlight reach into the structures? How readable was art displayed in the temple's interior under the light produced by lamps or torches? How does a monumental structure's exterior appear to visitors at specific times in the year and day? These are ideas which (at least in religious sites) may have been linked to religious beliefs or specific cult aims.

Another important recent study, has added the element of kinaesthesia and its impact in experiencing digital reconstructions (Slaney et al., 2018), moving thus beyond static 3D models. It is true, as the authors observe, that visualizations alone cannot offer complete experience of a space, at least not to the extent that VRM and Motion Tracking engines can. Until now, these technologies have been employed for reconstructions of the past mainly within the gaming industry (for a further discussion see Chapman, 2017; Chapman et al., 2016). Our testing of the VRM of Apollo's Bassae temple demonstrates explicitly that the ability to move within a structure with a complete roof and walls (even without accounting for light, offers a very different experience and sense of architecture, scale and overall visual impression (Price, 2019). More so, when lighting conditions change (i.e. time of day, weather, natural or artificial light). This kinaesthetic analysis of the temple, does not form part of the current paper. Here, we are only concerned with the observations relating to the rising sun's movement inside the temple's *adyton*.

For the discussed VRM, orientation, architectural, and landscape data were entered on the VR gaming platform, Unreal Engine 4 (UE4), which, although developed for gaming, facilitates photoreal visualizations. Virtual reality was preferred over a 3D reconstruction, as it allows for human interaction with the three-dimensional visual content and photoreal visualizations of space at different levels of immersivity (Forte, 2018). A unique benefit of the VRM is that with relevant equipment, we can virtually experience the temple and visual impact of the sun's movement in the interior through an avatar. The preference of a gaming platform for the creation of the VRM lies in the improved user engagement that gaming engines are aimed at. One of the aims of the study was to explore real time interaction, immersion and overall user experience, although these aims are not explored in the present paper.

The endeavour was not without difficulties and limitations. UE4 does not include any integrated solar or astronomical data and the available plugins developed so far, only include the sun's position as far back as the first century CE, which is several centuries after the date of interest. As a result, the sun's position and speed at sunrise on the dates of interest were entered manually in the UE4 simulation, in order to recreate the correct altitude of the sun at a given time during the dates of interest (for more information on this process see Price, 2019). The astronomical data was obtained from a combination of high-accuracy specialist astronomical software: Starry Night Pro and Stellarium. The VRM generates a visually compelling and accurate reconstruction of the moments when the sun entered the structure in antiquity, but naturally, some minor details of the temple had to be estimated. As this endeavour was novel, at least for Classical archaeology, conventions had to be made. For example, the size of the model had to be controlled for development time purposes; the acquisition of detailed landscape data was the most challenging aspect, as no LiDar survey data exists for Bassae. Thus the landscape data used was that made available from NASA ASTER (Advanced Spacebourne Thermal Emission and Reflection Radiometer), which is of the same resolution as the data of Greek military maps. This means that the best achievable resolution was 30m per pixel, which, given the UE4 engine's inability to interpolate between the various heights of a quite mountainous landscape, resulted in a rather pixelated landscape, even after improving it through the Geospatial Data Abstraction Library toolset (*2018* GDAL/OGR 2.4.0 release) (Price, 2019). This obstacle, is however, of no consequence to the present study, as the surrounding landscape does not form part of the present analysis. The virtual simulation allows us to both test the hypothesis and experience the solar impact, as well as visualise the effect of the sun's movement on the temple's interior and its natural illumination throughout the year. The following analysis exemplifies the value of VRM in archaeological and archaeoastronomical analysis. It demonstrates that immersive VR technology can offer some understanding of ancient sensory experience and can help immensely in visualising and verifying contextual data.

4 Results

The VRM reveals that a sunbeam entered the temple’s side entrance at the spring equinox approximately 40’ after sunrise (Figure 4 top row).[1] It traced a path in the temple’s *adyton* for three hours from ca.5:30–8:30am. Upon entering the temple’s interior, the sunbeam appeared in the centre of the marble slab marked on the floor, moved along the west *adyton* wall and floor and eventually illuminated the base of the west oblique Ionic column, almost missing the base of the Corinthian column before withdrawing. If this was the location where the cult statue stood, it would have created an interesting effect. This simulation follows Copper’s argument of the permanent shut position of the south door leaf (Cooper, 1968, p. 107).

Figure 4. Virtual reality simulation model of the temple’s interior showing the visual effect of sunrise during the equinoxes between 500–100 BCE. **Top row:** progression of sunbeam at equinoxes with one door leaf open. **Bottom row:** progression of sunbeam at equinoxes with both door leafs open.

Figure 5. Sunbeam at sunrise on the equinoxes as visible from the temple’s interior

If both door leaves were left open, the effect would have been very similar, but in this case the sunbeam was thicker and would illuminate the entire width of the slab upon entering the temple (Figure 4 bottom row). As observed in the figures, the illumination of the Corinthian column is only visible from inside the *adyton*, or if one stands directly outside the east entrance. From the interior of the *sekos*, or the temple’s main (north) entrance, the sunbeam was visible, but its movement would have not been particularly noticeable and the illumination of the west wall would have been mostly hidden behind the oblique SW column (Figure 5).

At sunrise, a week before the spring equinox, when the rising sun was aligned to the east entrance, the sunbeam entered the structure at a different angle (Figure 6). It illuminated the north end of the marble slab, the entire lower half (back and front) of the west oblique Ionic column and the Corinthian column to a larger extent than on the equinox. At both dates, the west part of the *adyton*, which according to one interpretation was the location of the cult statue, was only marginally illuminated by direct sunlight.

1 The roof and side door thickness were modelled following Spawforth’s illustrations (2006, pp. 156–157).

However, the reflective properties of bronze, would have extrapolated the luminance, and the duration of the effect would have seemed longer and stronger.

The VRM enables us to examine the movement of the sun from a number of positions. One such example is the sunrise at the equinoxes from outside the temple's main entrance. If we look to towards the east at the moments when the disk of the sun rose in antiquity above the horizon on the equinox, we observe that it rises behind the second NE external column and becomes visible after it has risen above the horizon (Figure 7 top row). A week earlier, when the sun's declination was the same as the orientation of the east entrance, the sun's disc became visible as soon as it started to rise above the horizon, adjacent to the south of the same column (Figure 7 bottom row).

Figure 6. Virtual reality simulation model of the temple's interior showing the progression of the sunbeam a week before the equinoxes when the sun was aligned to the east entrance between 500–100 BCE.

Figure 7. Virtual reality simulation model of the temple's exterior between 500–100 BCE. **Top row:** progression of sunbeam at equinoxes. **Bottom row:** progression of sunbeam a week before the equinoxes.

Current knowledge of the Arkadian calendar and the absence of any indication on the timing of Apollo's festival in Bassae, do not allow us a further investigation on whether this occurrence functioned as an equinoctial marker, or indeed of the intentionality of this effect. Similarly, the path and duration of the sunbeam in the temple's interior, changes during the year and it is not possible to be more conclusive in the absence of further contextual material.

We observed that the light beam shining on the west wall was invisible if the observer stood in the centre of the *sekos*. The corner slab of the *adyton*'s SW corner, may have been slightly raised (Miles, 2016, pp. 154–155), but whether this construction supported the cult statue, it cannot be concluded with certainty. Cooper identified a discrepancy in the positioning of the fifth and sixth exterior columns (from the south), outside the east entrance: they are positioned further apart than the rest of the columns. He measured the sixth column to have been placed further south by 0.028m (Cooper, 1996, pp. 129–130). Cooper's conclusion that this minor adjustment served the aims of the visual effect created by the sunbeam entering the *adyton* seems credible.

The VR model confirms Cooper's suggestion of an east doorway, which allowed a very thin, specific beam of light to enter the *adyton*, but not in the position he estimated. The shadow effect created by a strong lightwell in the confined space behind the Corinthian column, would have been impressive. The architecture of the temple's interior colonnade confirms the intention of manipulating a light-shadow effect at Bassae. The last row of interior columns (those standing on either side of the central Corinthian column) are positioned at an oblique angle (at ca. 45°), not at a right angle to the wall as the rest of the columns (Figure 2). The aim must have been to optimise the amount of light entering the temple's *sekos*. When the light from the east entrance entered the *adyton*, this arrangement would have operated like a funnel, directing the light into the centre of the *sekos*, flooding the temple's interior with light. Had these two columns been positioned at right angles to the walls, the effect would have not been as impressive, as the columns would have obstructed the reflecting light, allowing a smaller beam of light to enter the *sekos*.

5 Discussion

Apollo's return from the Hyperboreans marked the beginning of spring, an event of cosmological and astronomical significance, linked with a number of Apolline shrines (Boutsikas, 2015, in press). In the case of Bassae, the reconstruction of the sunrise effect visible during the spring equinox from the temple's east entrance strengthens this link with a possible festival celebrated at the time of the god's return and the concurrent arrival of spring.

Even if the canopy was not covering the temple, it would have been impossible to observe what has been revealed by the VRM, because the door opening has not survived intact and the sun's position has moved since the fifth century BCE. Total environment reconstructions have the potential to inform us on emotionality, cognition, and experience by combining light manipulation. They allow us to integrate architecture and ritual activity within its original temporal setting, offering an improved understanding of ritual experience in a way that it is not possible to achieve through traditional methods of enquiry.

VRM is not imperative for total environment reconstructions. Other types of digital reconstructions can have equally informative and revealing results. Total environment reconstructions are particularly informative when the timing of the cult rites is known. Such examples discussed elsewhere are the timing of the Panathenaia during Draco's annual upper culmination after sunset (Boutsikas, 2011) and the timing of the Athenian Arrephoria at the time of the heliacal rising of the constellation of the Hyades (Boutsikas & Hannah, 2012). In some exceptional cases where we are lucky to have surviving literary sources, we are able to piece together such an experience. For example, Euripides' mostly lost tragedy *Erechtheus*, surviving only in fragmentary form, gives us necessary information about the connection between the sacrifice of Erechtheus' daughters and their catasterism as the constellation of the Hyades, linking the festival commemorating the girls' death with the movement of the constellation as witnessed from the Acropolis (Boutsikas & Hannah, 2012). Similarly, Alkman's *Partheneion* describes a ritual at a precise moment in time in the year, which allows us to recreate the rite and with it, the entire setting as was orchestrated in ancient Sparta (Boutsikas & Ruggles, 2011). As these case studies demonstrate, the reconstruction of a night-sky at the time when ritual performances were taking place in specific locations is capable of contributing a great deal to our understanding of ancient ritual experience.

The present analysis shows that through reconstructions of the night-sky, we are able to reveal that religious space and architecture were integrated in the structure of the cosmos, and may have influenced experience and memory of religious festivals. Architecture was imbedded in ancient ritual experience. Orientations, lines of sight, spatial movement – in other words, methods based on a space syntax – become particularly important in enriching interpretations on perception. At Bassae, the impact of sacred experience would be completely different without the east entrance of Apollo's temple. The suggested interplay with light and darkness occurs at the time in the year when the balance between daylight and darkness shifts. The links with astronomical events for time-keeping purposes forms one aspect of the interweaving of Bassae with its environment. Apollo's cosmological role complements our understanding of the impact of these occurrences on experience. Light can be a compelling agent, even in day-to-day activities; more so in religious contexts, where it can be used to orchestrate performances. It is easily understood that the use and manipulation of light in such spaces, does not simply aim at facilitating the intended activities, but it is also used in a more imaginative way, to hint at power relations and spirituality, as well as being used as a metaphor, to intensify experience and inscribe memories. Light can be a powerful transformative tool in creating atmosphere, sculpting areas and affecting emotions (Bille & Sørensen, 2007, p. 271; Sorrell, 2005, pp. 58). In addition to their attributes, light and darkness have been seen as the metaphors of 'absolute metaphysical counterforces' (Blumenberg, 1993, p. 31). In ancient Greek thinking, the god Helios (Sun) was 'all-seeing', denoting the ability of light to permeate everything, to reveal the true shape of things, and the truth. Just like Apollo, the god of light and divination, who could not speak a lie and revealed divine wishes to men through his oracles.

At the same time, the practical use of these links cannot be refuted. The movement of the sun could have also functioned as a temporal signifier of the arrival of the correct time for the rituals to take place. If we consider these astronomical occurrences as purely coincidental, total environment reconstructions offer at the very least a new dimension to our understanding of the surrounding land-and skyscape. If we accept some intentionality, the occurrences seem to link the cosmos with earthly locations, they tap memory, and strengthen identity. During these events, ritual performance was in tune with the cosmos.

Architectural form transforms experience 'spatially, metaphysically psychologically, emotionally and associatively' (Jones, 2000; Wescoat, 2012, p. 66). The light-shadow effects in Apollo's Bassae temple, may have been aimed at creating lasting memories of the divine encounter. Worldviews are shaped and influenced by personal experience and memories, which assign specific meanings to objects, ideas, perceptions. Shared experiences, shared memories, can lead to shared worldviews. And, inevitably, an essential component of ancient worldviews was the sky (Ruggles, 2005, p. xii).

Place as a notion involves a space that can not only be remembered and imagined (Lyndon, 2009), but also space in the Aristotelian sense, which has the ability to *contain* (*περιέχων*, Physics 4.210b) — the ability to hold meanings and memories of individual experiences, but also memories constructed through collective interaction (Feld & Basso, 1996; Jones, 2007, p. 63). The sense of a place seems inseparable from what Ruth van Dyke and Susan Alcock called 'a sensual experience' (2003, p. 6). As exemplified in ancient Greek religious spaces and festivals, the sense of a place was inextricably bound with the land- and skyscape, mythical narratives, time, performance, movement, etc. — activities incorporated in all manifestations of religious practice (see for example, Alcock, 2002, pp. 1–13). Forty years ago, Maurice Halbwachs discussed the function of the built environment as a repository of conscious and unconscious collective memories and the idea that these memories can be challenged and strengthened through actions, practices, and performances. Through these processes, emotional attachments are created between communities and their environments (Halbwachs, 1980, p. 140). Sanctuaries were obvious spaces for forging, negotiating, and propagating memory, even in their early phases. Freitag's study on Olympia for example, argues that Olympia was such a space from the 'earliest time' of its existence and demonstrates the difficulty in trying to separate memory from religious spaces (Freitag, 2011, p. 72). The areas carrying cosmic significance are perhaps 'the most effective carriers of social memory' (Crumley, 1999, p. 271), and digital technology can help us greatly in decoding these functions.

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