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Daniel J. Ryan^a

^a Faculty of Architecture, Design & Planning, University of Sydney, Sydney, Australia

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Sunshine and shade in the architecture of Eileen Gray

Daniel J. Ryan*

Faculty of Architecture, Design & Planning, University of Sydney, Sydney, Australia

Eileen Gray's houses along the Côte d'Azur 'Villa E1027' (1926–1929) and 'Tempe à Pailla' (1932–1934) are noted as 'among the first convincing attempts to adapt Modernist forms to a hot climate'. Her published drawings and commentary display a preoccupation with well-being and a strong interest in geometry, movement and daily ritual. By organizing the circulation of her buildings in relation to the path of the sun, Gray connected these rituals to solar rhythms. Villa E1027 was analysed using bioclimatic theory and computer simulation which brought to light new evidence of solar alignments in Gray's architecture along with rigorous design of solar shading, and considered use of thermal mass. Her writings to accompany the publication of the building display a critique of the application of hygiene that indicate an environmental awareness that is only picked up in the later bioclimatic theory of the 1960s. This building is a case study of significant interest for early modern environmental architecture.

Keywords: Eileen Gray; bioclimatic simulation

INTRODUCTION: HYGIENIC COMFORT

It is true that many works are a bit cold, but isn't that because we are influenced by the recent past? And aren't the principles of hygiene partly responsible for this coldness that disturbs us?

Yes! Hygiene to bore you to death! Hygiene that is badly understood, because hygiene excludes neither comfort nor activity. No the avant-garde is intoxicated by mechanization. But there is more than mechanization; the world is full of vivid allusions, vivid symmetries that are difficult to discover, but nevertheless real. Their excessive intellectualism suppresses that which is marvellous in life, just as their misunderstood concern for hygiene makes hygiene intolerable (Badovici and Gray, 1929).

This exchange forms part of a number of dialogues between the architects Jean Badovici and Eileen Gray published in the modern architecture journal *L'Architecture Vivante* in the 1920s. These nuanced debates offer rare insights into Gray and Badovici's way of thinking. Hygiene is not dismissed by the protagonists; rather, they bemoan its misapplication, and redirect the debate on hygiene to consider both comfort and activity. In many ways this concern for well-being, or as Gray puts it, *joie de vivre*, foreshadows the bioclimatic theory of Olgyay (1953). Indeed, her houses are noted as 'among the first convincing attempts

to adapt Modernist forms to a hot climate' (Hecker and Müller, 1993).

Eileen Gray had come to architecture quite late in life, having first gained a reputation for her lacquer. This was followed by furniture and interior design – a trajectory of scale from small objects to enclosures. Her early theoretical projects reworked the designs and spatial principles of Adolf Loos and Le Corbusier towards an architecture that explored the relationship between inside and outside, daylight and ventilation and the interdependence of spaces (Diamond, 1989). Initially assisting Jean Badovici, the Romanian architect and publisher of *Architecture Vivante*, she gained her own voice in two houses located along the Côte d'Azur in France, known as 'E1027' (1926–1929) and 'Tempe à Pailla' (1932–1934).

Gray's house designs prior to the Villa E1027 may be seen as learning tools leading to her first built work. Her earliest project, a three-storey house, was a reinterpretation of the Venetian *Villa Moissi* by Adolf Loos which she saw presented at the *Salon d'Automne* of 1923. Her design is less concerned with Loos' interior architecture; rather she investigates the role of terraces and external staircases to connect inside to outside (Wang, 1996). The 'House for an Engineer' of 1926 shows an adherence to both the planar dynamicism of *De Stijl* and also to Le Corbusier's *Five Points of a New Architecture* where a floating white box is raised over a manipulated ground plane (Wang, 1996).

*Corresponding author: Email: d.ryan@sydney.edu.au

Ground floor walls extend into the landscape, and furniture is kept to the centre of the plan, allowing free movement throughout the building. This furthered Gray's investigation of the relationship between inside and outside.

This previous investigation of the interior and external spaces would allow Gray to consider not just the visual implications of moving between inside to outside but also thermal and psychological issues. Functionalism, as espoused by the CIAM, used hygienic theory to relate buildings to their environment. As the quality of the environment in hygienic theory was measured in terms of health rather than personal comfort, Gray and Badovici's architecture shows a wariness of functionalist and hygienic doctrines but not a complete rejection.

E1027: THE CHOREOGRAPHY OF CLIMATE

The site and climate

The steeply sloping site (Figure 1), located in Roquebrune-Cap Martin, is approximately 20 km from Nice, France and close to the principality of Monaco. The plot, located between a rail line and the rocky seashore, is accessible only by foot or sea. The site was a former lemon grove, whose terraces were kept by Gray.

The Nice climate is a Mediterranean climate with a Koppen climate description of Cs meaning a dry summer subtropical (Mediterranean) climate (ASHRAE, 2001). Heating degree days are greater than cooling degree days from mid-September to mid-March while solar degree days are greater than heating degree days from mid-April to mid-October, suggesting the need for solar control in summertime. Daily solar radiation varies between an average of 2869 Wh/m² in December to 8359 Wh/m² in July.

The climate is relatively benign in summertime. The psychrometric chart (Figure 2) shows that summer temperatures lie slightly outside the summer comfort zone. Thermal mass



Figure 1 | E1027 viewed from Roquebrune beach
Source: Ryan (1999)

effects and night ventilation can increase the area of the comfort zone to mitigate summer temperatures while a glazing ratio of 60% on the equator-facing façade combined with medium levels of insulation increases the winter control zone to cover winter temperatures.

Solar orientation

The Nice climate was analysed using the Weather Tool Program (Square One, 2005) to find the best orientation according to the sol-air approach. The optimum orientation is 172.5° from the north. The cut-off angles for good orientation are 135° and 222° from the north, respectively. The terraces generally face 228° from the north, which falls outside the zone of best orientation. Rather than follow these contours, Gray shifts the orientation of E1027 slightly to 212.5° from the north, which falls within the zone for good orientation. The building is therefore sited at a slight skew as it negotiates the constraints of the lines of the site boundary and the optimization of solar access.

However, looking closer at the solar geometry of the building, one notes that the long axis of the building corresponds closely to an axis drawn between the winter solstice dawn azimuth angle and the summer solstice azimuth angle at dusk, respectively (Figure 3). Gray makes no mention of designing for these events, nor have any other scholars commented on this. However, given that the building appears to shift away from the general contour lines, without orienting due south, the alignment to these solstice lines provokes questions as to whether Gray and Badovici worked with solar charts in orienting the building. Archival research of the Eileen Gray archives at the Victoria and Albert Museum, London found a series of photographic plates, depicting images of Stonehenge and a plan of Teotihuacan, ancient sites famous for their solar geometry.

Sunlight, time and activity

Gray's drawing (Figure 4) relating movement of occupants to the pattern of sunlight is unprecedented. By focusing on issues of human motion and stasis in relation to the daily cycle of sunlight, Gray's plan diagram suggests the possibility that architecture devoted to leisure can reawaken a natural – that is, a non-numerical – understanding of time (Constant, 2000, p115).

Analysis of the drawing shows that lines are drawn at 45° to create hatched areas signifying the beginning and end of sunlight in relation to areas of activity. The activity lines show occupant and furniture movement in relation to the sunlight. This describes a natural choreography based on solar movement rather than mechanized functionalism.

Mid-summer shadow ranges (Figure 5) are different in Gray's diagram (Figure 4). In fact, sunlight reaches the salon glazing until 19:30 in summertime, as shown in the shading mask for the westernmost window. As a general organizing diagram, Gray's graphic is clear.

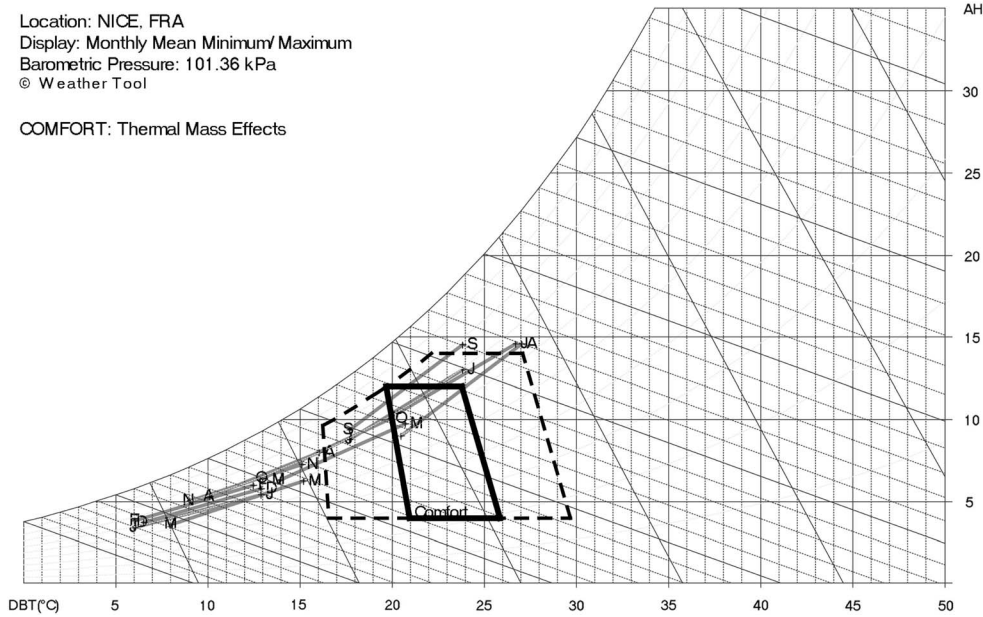


Figure 2 | Psychrometric chart for Nice
 Source: Square One (2005)

E1027: THE SELECTIVE ENVIRONMENT

The four problems of E1027

Gray describes four problems which the designers of E1027 focused their attention on: windows, shutters, the independence of rooms and the kitchen. All four problems have environmental consequences. The design of the windows and shutters reflects an interest in mass production. Emphasis was placed on the opening mechanism for the windows so

that they could slide into a wall, fold back to the window jambs or pivot to block views in and out but still allow for ventilation. Three types of windows were created with an emphasis on privacy and control of views.

Shutters had to allow sufficient ventilation when in use. Gray uses a biological metaphor for the design of shutters comparing them to eyelids and windows to eyes (Badovici and Gray, 1929). She acknowledges the neglect by designers for the design of shutters, noting that ‘all the current combinations lead to the same result: insufficient ventilation when the shutters are closed’ (Badovici and Gray, 1929 trans. Constant, 2000, p241).

All rooms were given independent access to the outside, while entrances to the rooms were concealed. The independence of rooms sought to give a measure of controlled privacy to occupants combined with a careful modulation of indoor and outdoor space. Therefore, each room (with the exception of the maid’s room) has separate access to the outside. The quantity of terraced space beside rooms is proportional to the size of the adjacent room. The level of comfort increases as the scale of rooms increases with increased thermal choice in larger rooms.

The kitchen was designed to separate odours from the rest of the house and had to be usable in summer and winter. Located at the rear of the house, it is both an indoor and outdoor kitchen and refers to the vernacular of the area. ‘The kitchen layout has been suggested by the customs of the peasant women of the region who prepare their meals outside during the summer and inside during the winter

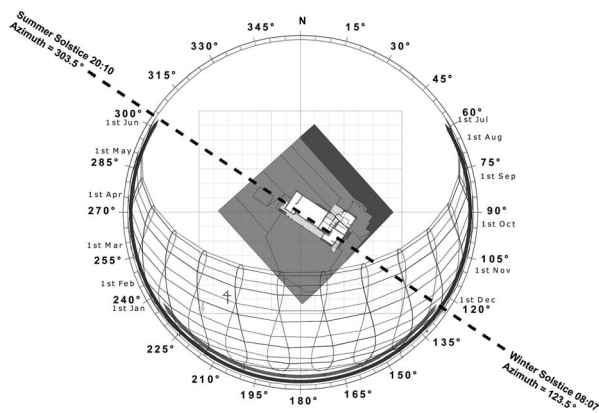


Figure 3 | Building orientation to the solstices
 Source: Ryan (2008)

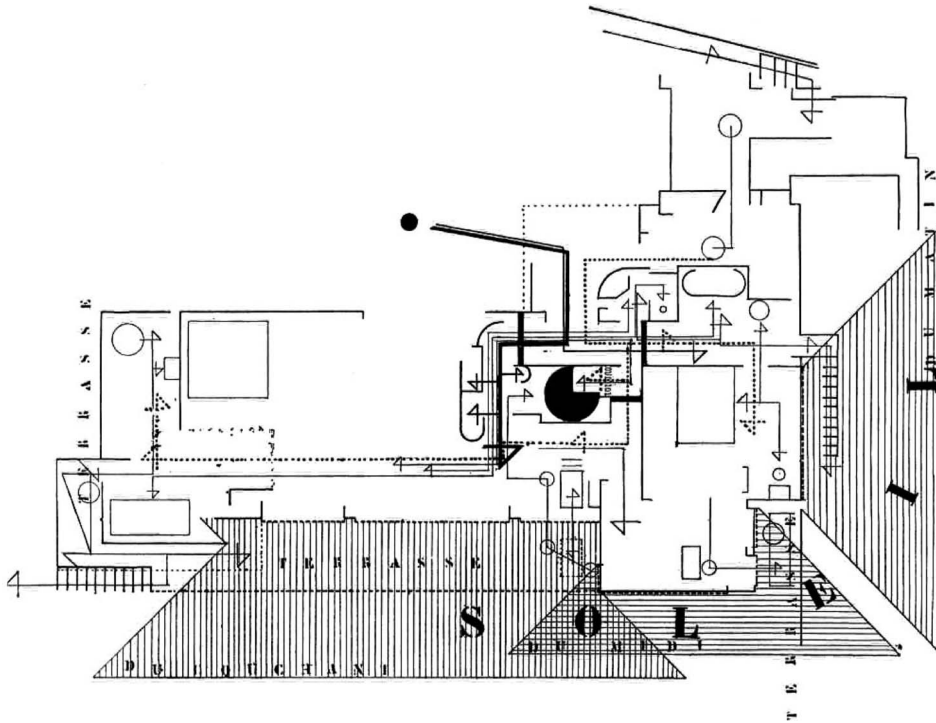


Figure 4 | Circulation and sunlight diagram
 Source: Badovici and Gray (1929)

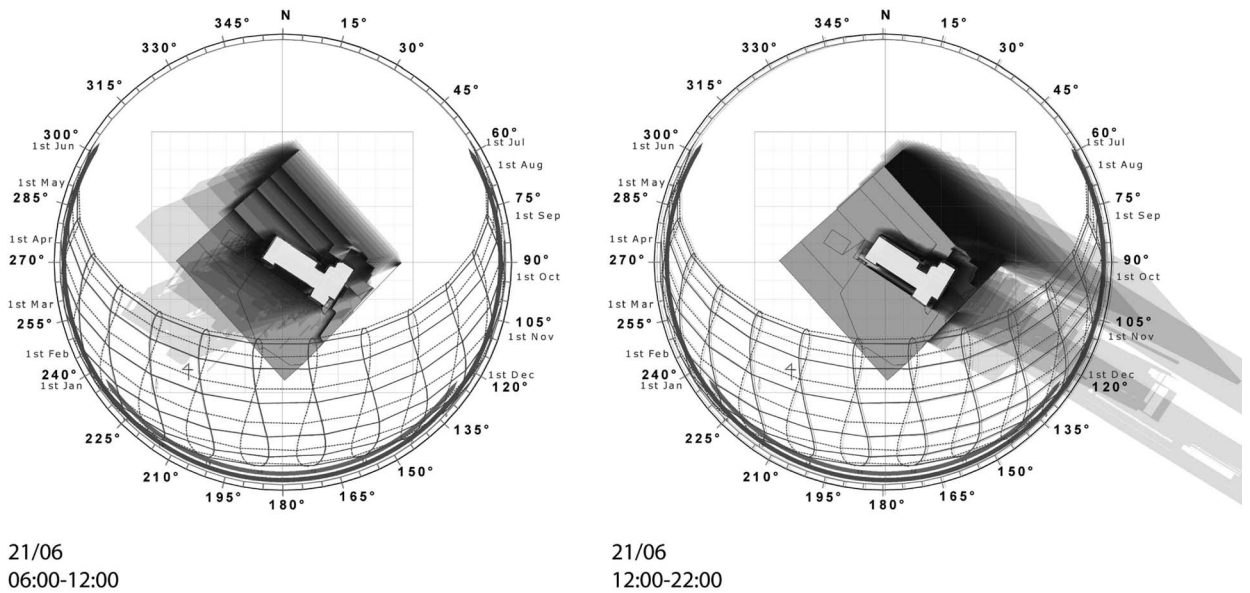


Figure 5 | Summer solstice shadow range
 Source: Ecotect (2008)

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and bad weather' (Badovici and Gray, 1929 trans. Constant, 2000, p244).

Shading devices

Shading masks were drawn for the overhangs and movable shades on the building (Figure 6). Fixed awnings occur to the south and west of the building while the sliding shutters serve as a universally applicable shading device irrespective of orientation. They give near 100% shade when closed, with the cover of the shutters carefully detailed to allow ventilation from below but to block sunlight between the shutters and glazing from the side and from above. The canvas awning acts to shade the salon windows. It is removable for winter solar gain. Table 1 lists the types of shading devices.

A solar model in Ecotect (Square One) studied the terrace to look at the effect of the awning in reducing radiation onto the glazing of the salon in summertime. The results were compiled and tabulated comparing beam radiation with incident radiation on the glazing with and without the awning (Figure 7). The results show the effectiveness of the canvas awning at reducing radiation, with only a small amount of radiation entering at midday.

Shutters are designed to allow varying control of ventilation (Figure 8). A gap between the shutter rail and the windows allows for a constant level of background ventilation. The shutter pivots within its frame to increase ventilation into the room without sacrificing shade. It is likely that the building is easily ventilated due to the large areas of openings in the building and the shallow plan (the salon is less than 6m wide with a room height of 2.9m).

Thermal simulation

A single zone thermal model of the salon was made in Ecotect to study the effect of the awning and thermal mass in the roof. Construction of the building is generally of reinforced concrete with a hollow terracotta block infill (250mm external walls). The creation of a thermal model for a historical building throws open a number of difficulties. Firstly, data for materials are based on current properties of construction materials. It is likely that the material composition of concrete will be different at E1027 compared to the lightweight concrete of today. In addition, the major infill material for the building is a hollow terracotta block whose exact porosity is not known. Without testing the building itself on site or obtaining detailed survey information from the conservation architect, the model may only serve to highlight the relative success of using one type of construction in relation to another. For simplification, the terracotta block was replaced by a lightweight concrete block in the thermal model. Assumptions for the time lag of build-ups were based on closest similar wall constructions in the Ecotect material library.

The model looked at the internal temperature profile on the summer solstice studying the effect of the awning, and the ceiling with high thermal mass compared to a ceiling

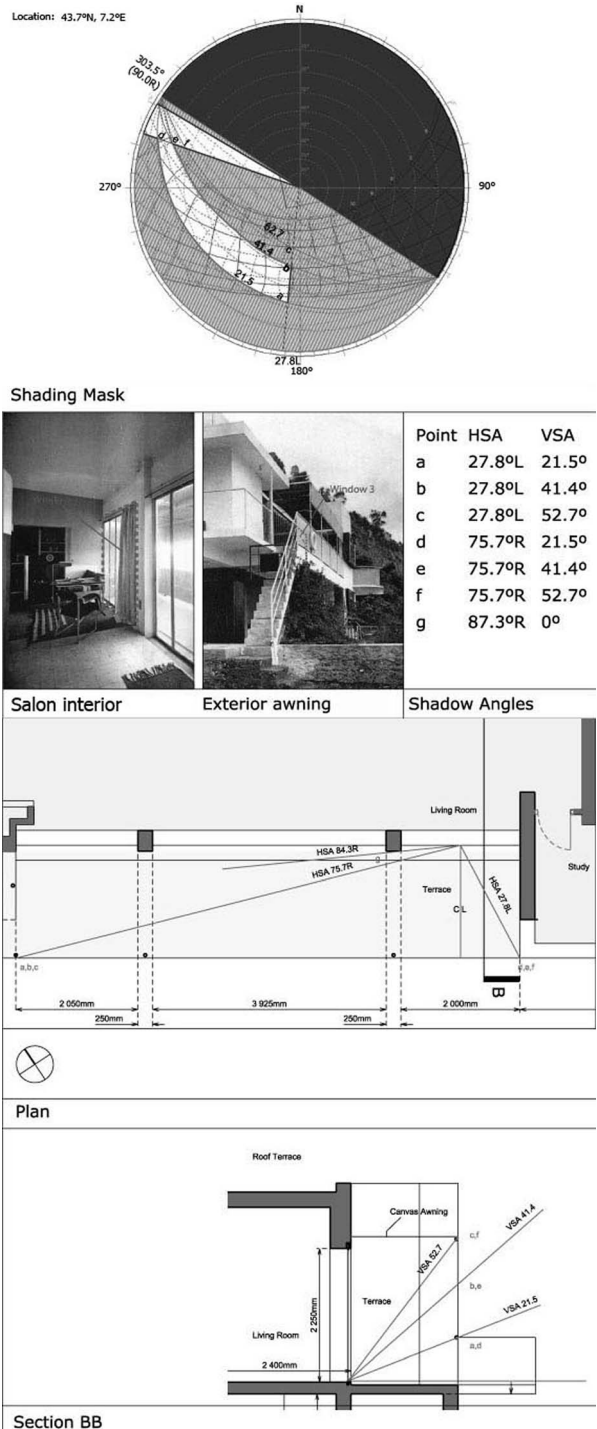


Figure 6 | Terrace window and awning shading study
Source: Ryan (2008)

Table 1 | Shading devices

Shade	Shade type	Orientation
Fixed awning	Fixed	S,W
Removable awning	Adjustable	S
Sliding shutters	Adjustable	N,S,E
Sliding door	Adjustable	E,W

with low thermal mass, for example, terracotta roof tiles on timber beams with no insulation. The results were collated and plotted against each other and the external temperature (Figure 9). No ventilation is assumed due to the lack of CFD modelling in the Ecotect program. The graph still allows for comparison of the relative importance of thermal mass and shading in the creation of a pleasant internal environment in the salon.

The graph clearly shows the thermal damping due to the ceiling where the temperature remains below the outside from 09:00 to 20:00 but stabilizes above the external air temperature during night-time. Night ventilation could reduce the internal temperature further. The awning reduces temperatures by cutting out radiation, but this is not sufficient to lower temperatures in the middle of the day due to the low thermal damping effect of the tile and timber roof.

CONCLUSION

The house may be considered a bioclimatic building in terms of how it relates to its site, its concern for passive cooling techniques through the use of shading devices and thermal



Figure 8 | Sliding shutters – as found by the author in 1998
Source: Ryan (1998)

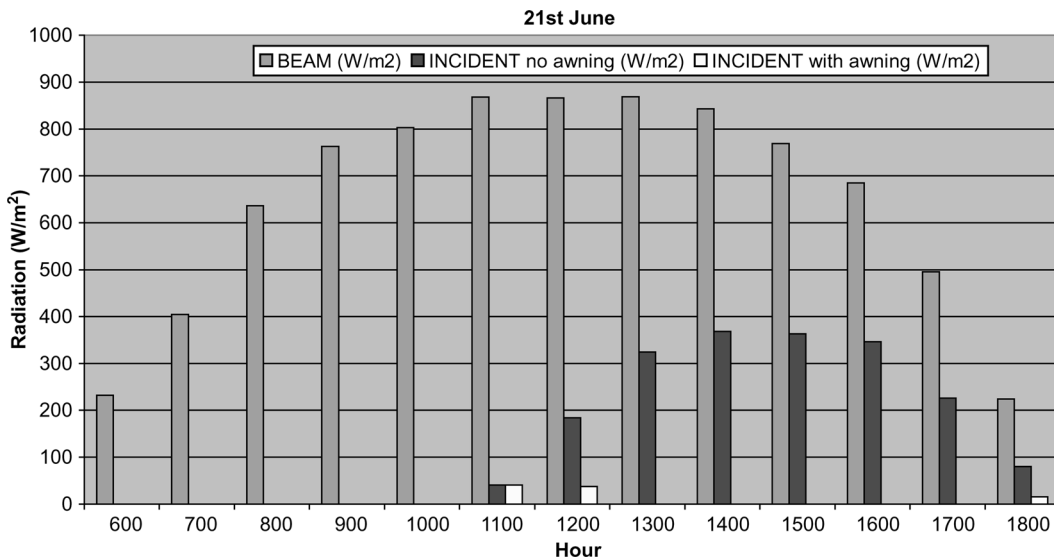


Figure 7 | Terrace window and awning radiation study
Source: Ryan (2008)

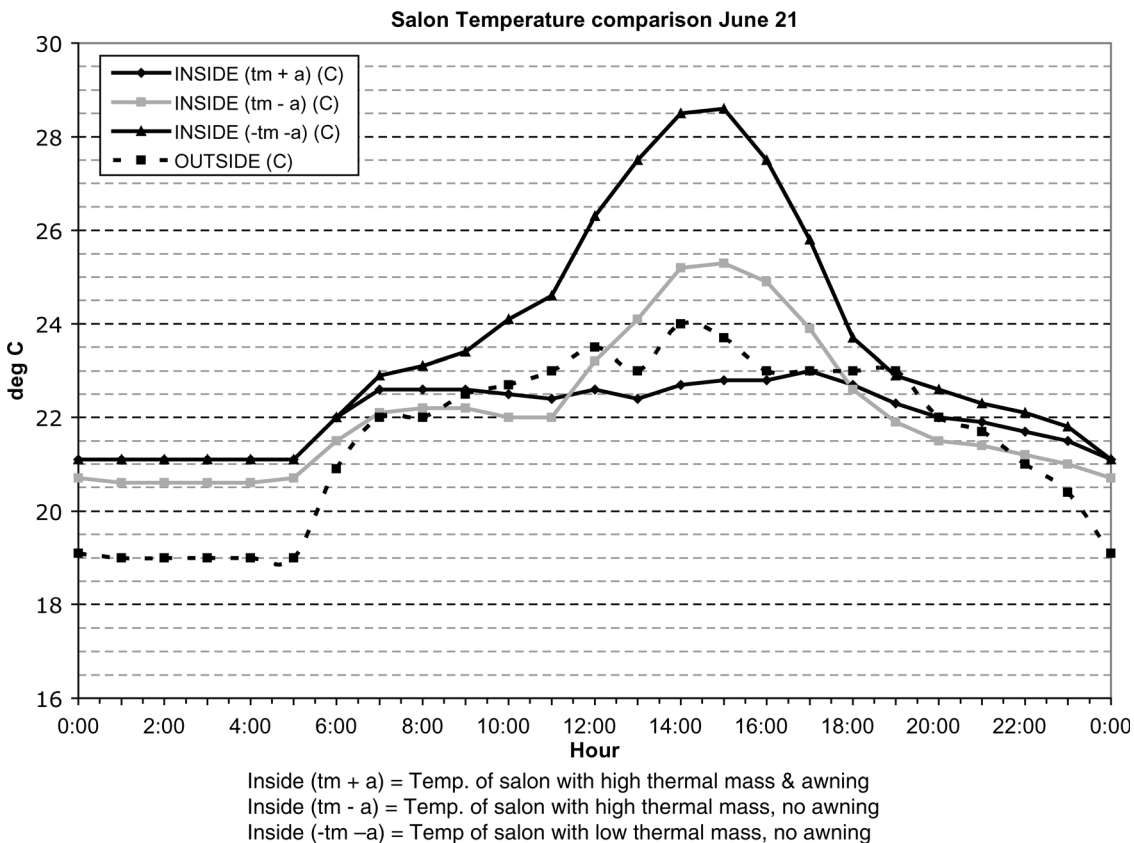


Figure 9 | Internal temperature comparison

Source: Ryan (2008)

mass. It carefully orients activity to solar orientation, setting up a series of poetic relationships in the process. Other than the sunlight diagrams, Gray and Badovici do not attempt to graphically interpret the local climate. However, there is an evident awareness of local customs and weather patterns. The building contains a high level of adaptive opportunity due to the manner in which rooms are isolated but still give the option of being indoors, outdoors, at rest, study or cleansing oneself. The emphasis on the immersion of the body in its environment through different forms of bathing – sun-baths, shower-baths and sand-baths resonate with the Olgyays' emphasis on man as the measure of everything (Olgyay and Olgyay, 1963).

Gray and Badovici's intuitive understanding has largely been proven correct in the way the building relates to its climate. Further study is required to see how the building performs in wintertime to investigate whether the large expanses of glass act as thermal conductors or solar collectors. Further study is required to look at how the building controls ventilation and relates to surrounding wind patterns.

The survey of attitudes to the environment at the time demonstrates the confusion between techniques to create healthier living environments and those for comfort. Gray critiques Corbusian principles to create one of the first modern dwellings appropriate to the Mediterranean climate and culture.

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