Nature, People and Place: Informing the Design of Urban Environments in Harmony with Nature Through the Space/Nature Syntax

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Abstract The Biophilia Hypothesis holds that there is a connection between humans and Nature which is innate: that when this connection is provided the human mind performs at peak, and when it is absent the mind is in a state of deterioration. Increasingly research supports the Biophilia Hypothesis: studies show that a connection to Nature provides psychological, physical, and emotional benefits. Concurrently, the world's urban population is rapidly growing and is expected to reach 70% of the world's total by 2050. Thus a dichotomy emerges: how do we maintain this vital and valuable human connection with Nature in an increasingly urbanising world? Building on previous preliminary publications, this chapter will update the findings of a novel, cross-disciplinary methodology called Space/Nature Syntax as developed and applied at Arcosanti's "urban laboratory" in the Arizona desert. The findings, which support relationships between visual connectivity to Nature and certain social interactions, present a unique understanding of the influence of Nature on human interaction with people and place. It will also present how informed design can fulfil the biophilic need and allow for the essential human/Nature connection to thrive, taking steps towards understanding how cities can be built in harmony with Nature.

Keywords Biophilia · Connectedness to nature · Urban public space
Spatial analysis · Space syntax · Social interaction · Observations
Environment related behaviour

1 Biophilia and Urbanisation

This chapter derives from research which has developed the Space/Nature Syntax, a methodology that explores what effect proximity to the natural environment from the built environment has on social interactions, with Arcosanti, Arizona, USA as case

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study. We will present the findings of the Space/Nature Syntax application at Arcosanti within the context of current knowledge of human interaction patterns within urban public spaces. The work aims towards identifying opportunities for informed design to increase visual contact with nature within built environments, in turn preserving and enhancing our biophilic connections, and facilitating social interactions.

In 1984 the Biophilia Hypothesis was proposed by E.O. Wilson as an evolutionary theory which presented the relationship between humans and Nature as innate. Wilson proposed that we are born with basic mental facilities which are awakened and stimulated through contact with the natural environment. When this natural contact is provided the mind can develop and thrive; when contact is absent the mind is mentally deprived (Krčmářová 2009; Clowney 2013). Recent scientific studies increasingly support the Biophilia Hypothesis; contact with the natural environment is repeatedly shown to decrease stress, symptoms of mental illness, and recovery times in hospitals, and increase concentration in school children and happiness in workplaces (Frumkin 2001; Taylor et al. 2002; Giles-Corti et al. 2005; Matsuoka and Kaplan 2008; Taylor and Kuo 2009; Barton and Pretty 2010; Nisbet and Zelenski 2011; Logan and Selhub 2012; Beil and Hanes 2013).

Paolo Soleri, an Italian-American architect, artist and philosopher began the construction of Arcosanti in the Arizona desert in 1970, as an "urban laboratory" (Soleri 1993) designed and built according to the principles of Arcology, Soleri's proposal for designing cities that achieve an equilibrium between humans and Nature. Soleri's Arcology (ARChitecture + ecOLOGY) theory calls for cities that are three dimensional, compact and vertical, providing the high density environment he felt was essential while minimising ecological impact. Additionally, vehicles would have no place in an Arcology, with the proposed transit methods being walking and cycling, thus the city would return to being designed around the human, not the automobile. Soleri's Arcology theory goes beyond an urban planning theory, embodying an evolutionary theory which he named the Miniaturization-Complexity-Duration (MCD) paradigm. The MCD paradigm holds that, in order to ensure that our evolutionary potential is achieved, humankind needs the kind of close contact with other humans that dense, compact arcologies would provide (Soleri 1969; Soleri and Strohmeier 2001; Soleri and Sarda 2007; Soleri et al. 2012; Soleri and McCullough 2012) (Fig. 1).

The theories behind Biophilia and Arcology align when considered alongside the shift from rural living to urbanisation that has been underway since the Industrial Revolution. In 2008 over 50% of people on the planet were living in cities, and it has been projected that by 2050 this figure will be 70% (P.R.B. 2008; W.H.O. 2014). This shift of population towards cities is coupled with a general rise in total world population. In 2011 the global population reached 7 billion; in 2016 it was estimated at 7.3 billion (UNFPA 2015a). By 2050, the UN estimates that the global population will be 9.6 billion: if this projection proves to be a reality, and the projection of the World Health Organisation that 70% of the world's population will live in cities also holds true, then this will translate to a global urban population of 6.7 billion—almost double the 3.4 billion urban inhabitants in 2008 (Berry 2008; UNFPA 2015b). The potential economic, cultural, political, and social benefits of urban living have increasingly drawn people to the urban environment. This means increasing numbers of people

Fig. 1 Arcosanti. *Source* Author

who seek all the things city life has to offer are also in danger of sacrificing their biologically essential connection to the natural environment.

Where Wilson believed that proximity to Nature is beneficial, innate, and essential, Soleri's Arcology theory and MCD paradigm holds that proximity to both Nature and fellow humans is beneficial, innate, and essential, and offers a more rational planned response to the challenges of our age (Grierson 2016). The natural environment is not designed for humans: when in Nature humans are a part of a larger biological system which doesn't and shouldn't put our needs first. But since cities are designed by and for humans, to be designed well they must address our various and complex needs. With strong scientific support for the Biophilia hypothesis, it is becoming increasingly evident that, alongside our physical and social needs, we have a biological need for Nature to be present in our cities. Arcosanti, a 15-acre settlement surrounded by over 800-acres of protected natural landscape (Cosanti Foundation 2013), provides a timely opportunity to explore how humans respond to experiencing simultaneous built and natural environments, and explore how such a settlement can inform city design that provides physical, social and biological needs.

2 Social Interactions in Built and Natural Environments

Proximity to Nature, and the effect of this on humans, has become a significant field of scientific study in the last 40 years. Yet the majority of studies on the human-Nature relationship still focus on health benefits, with the effect on social interactions usually limited to a side point within a wider study. Those which do touch upon social interaction raise an intriguing duality with regards to how people

Fig. 2 Social events at Arcosanti. *Source* Author; Cosanti Foundation www.arcosanti.org

interact with others when in Nature. There is a strong narrative of people viewing Nature as a place for solitude and respite yet also a strong narrative of people viewing Nature as a place for gathering and socialising (Barnhart et al. 1998; Jim and Chen 2006; Kingsley et al. 2009; Peschardt et al. 2012; Rostami et al. 2014; Baklien et al. 2016). While the majority of studies are set in a natural environment there are similar results from studies looking at urban nature. Urban public space use was suggested to be influenced or linked to natural elements: where there was grass or water in public spaces, there tended to be people, and again the conclusions were mixed with some researchers linking the natural elements as appealing for solitude and peace, and others to socialisation particularly through children playing (Coley et al. 1997; Roovers et al. 2002; Huang 2006; Dowdell et al. 2011) (Fig. 2).

In the midst of a city true Nature is unachievable: even the most famous and loved public urban parks like Central Park in New York or Hyde Park in London are man-made Nature. Yet, there is evidence which points to man-made Nature as still having the potential to trigger biophilic responses: studies which consider small interactions with natural elements within the built environment achieved similar results to those which explored biophilic responses in "true" Nature or wilderness (Heerwagen and Orians 1986; Salonen et al. 2013). This discovery is significant when considering the juxtaposition between Biophilia and urbanisation: while it may be impossible to provide true Nature in an urban environment, it is certainly possible to integrate natural elements which appear to have the potential to produce similar biophilic responses, and thus achieve the proven psychological and physiological benefits.

Additionally where physical access to Nature is difficult or impossible, a view of Nature has been suggested to have similar if not identical benefits (Hartig et al. 2003; Stigsdotter 2004). In fact, a number of studies found that merely looking at images of natural scenes produced the same psychological reactions and physical benefits that taking a walk in a forest would achieve (Ulrich 1979, 1984;

Ulrich et al. 1991; Sherman et al. 2005; Raanaas et al. 2012). Thus the potential of a visual connection to Nature emerges as an exciting prospect when related to urbanisation and increasing Biophilia within cities. A view of Nature, however, has never been explored alongside social interaction: there were no studies identified through this research which sought to establish if viewing Nature influenced social activities and human behaviour in the same way as physical access to Nature. This is a particularly significant opportunity for exploration given the aforementioned duality in the relationship between social interaction and the human-Nature relationship.

3 Towards a Space/Nature Syntax Methodology

The methodological development of the Space/Nature Syntax has been published previously: these can be referred to for full details of its components and how they are calculated (Munro and Grierson 2016; Munro and Grierson 2017). There are four components which will be described and referred to throughout the paper: **Space Syntax**; **Nature Syntax**; **Interaction Observations**; and **Correlations**. The Space/Nature Syntax evolved from Space Syntax, a method of spatial analysis developed by Hillier and Hansen (Hillier et al. 1976; Hillier and Hanson 1984; Hillier 1999; Hillier 2007) which gives statistical value to built spaces, allowing them to be analysed, adapted and planned by investigating the relationships between spatial layout and social, economic and environmental urban issues (UCL 2016). Space Syntax investigates how the arrangement of built spaces relative to each other produces strong urban environments. Space/Nature Syntax expands upon this understanding of the arrangement of built spaces to other built spaces, to create a "set of rules" for successful built environments which consider their relationship to the natural environment.

Space Syntax was used in this research to analyse 15 public spaces at Arcosanti in order to determine which, according to spatial configuration, should be the most and least likely to exhibit certain types of social interaction. This research uses the *Real Relative Asymmetry (RRA) value* which indicates how accessible a space is from all other spaces at Arcosanti. The lower the RRA value the more connected a space is, with values of 0.4–0.6 generally given to indicate very strong connection: these would be spaces which have strong and easy physical access to a high number of other spaces (Bafna 2003).

The **Nature Syntax** component of the methodology was developed through the research that this paper draws upon and produces the statistical measure *Visibility of Nature (VN) value*. The VN value represents the amount of natural environment visible from within a built space and is a single number between 0 and 1, with 1 being the maximum visual relationship to Nature possible. The VN value is reached by calculating the *Permeability (P value)* of the envelope of a space, and the *Naturalness of View (NoV value)* of what is visible through that permeable area, using the following equation:

$$VN = P \times NoV$$

Next, there were 300 **Interaction Observations** carried out at Arcosanti between February 2015 and February 2016 which established how people interacted with the spaces themselves, and other people within the space. The methodology for the observations was developed by conducting a review of observation techniques used in similar studies (Coley et al. 1997; Cooper-Marcus and Francis 1997; Goličnik 2007; Goličnik and Thompson 2010; Peschardt et al. 2012). All public spaces were observed for 30 min per observation, and four times in each of the following time frames, resulting in 20 observations per public space:

- 0600–0900
- 0900–1200
- 1200–1500
- 1500–1800
- 1800–2100.

Interactions were marked onto a prepared plan of the space using a prepared key with 4 categories of interactions being recorded: *Interaction with Space*; *Interaction with Others*; *Use of Space;* and *Visual Interaction with the Natural Environment (V.I.N.E.)* (Fig. 4).

Interaction with Space considered how a person was using the space, and was recorded as either *Active* or *Passive* with Active being an activity for which the space was being used, and which occurred in the space for more than 30 s, and Passive describing when the space was merely used as a through-route without interaction with any of its features.

Interaction with Others considered how a person interacted with other people within the same space, and used Hall's Proxemics (Fig. 3). Proxemics describes social interactions in terms of the distance a person places between themselves and others. *Intimate interaction* occurs from 0 to 0.5 m and is the distance at which strong emotions—positive and negative—are exchanged; a distance only close family and friends can enter; *Personal interaction* is between 0.5 and 1.2 m, the distance at which most conversation with those we are familiar with occurs; *Social interaction* is the most common distance at between 1.2 and 4 m and is the distance for interaction with acquaintances and colleagues; and *Public interaction* at 4–12 m is the distance one would use to address a group, or to indicate a desire to be alone in a crowd (Hall 1968; Ciolek 1983; Agnus 2012). For this research an additional category of *Alone* was added to indicate when only one person was present in a public space.

Use of Space refers to the degree to which an Interaction with Space was planned prior to its occurrence. There are two criteria within the category; *Intended* and *Spontaneous*. Intended activities were those scheduled or planned for a specific space and time. Spontaneous activities were those which were occurring without planning or direction from anybody other than those carrying out the activity. It was possible to determine whether an activity was Intended or Spontaneous due to daily

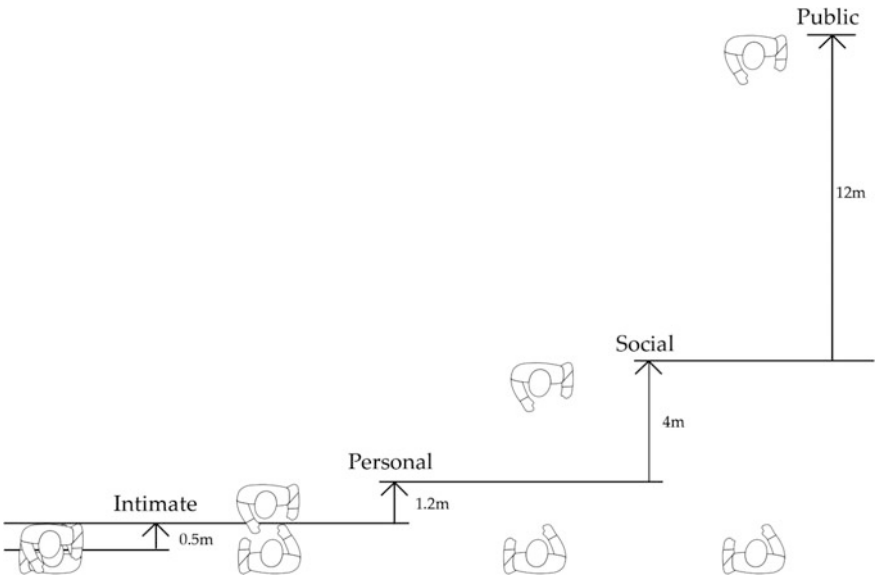


Fig. 3 Diagram of Proxemic distances. *Source* Author

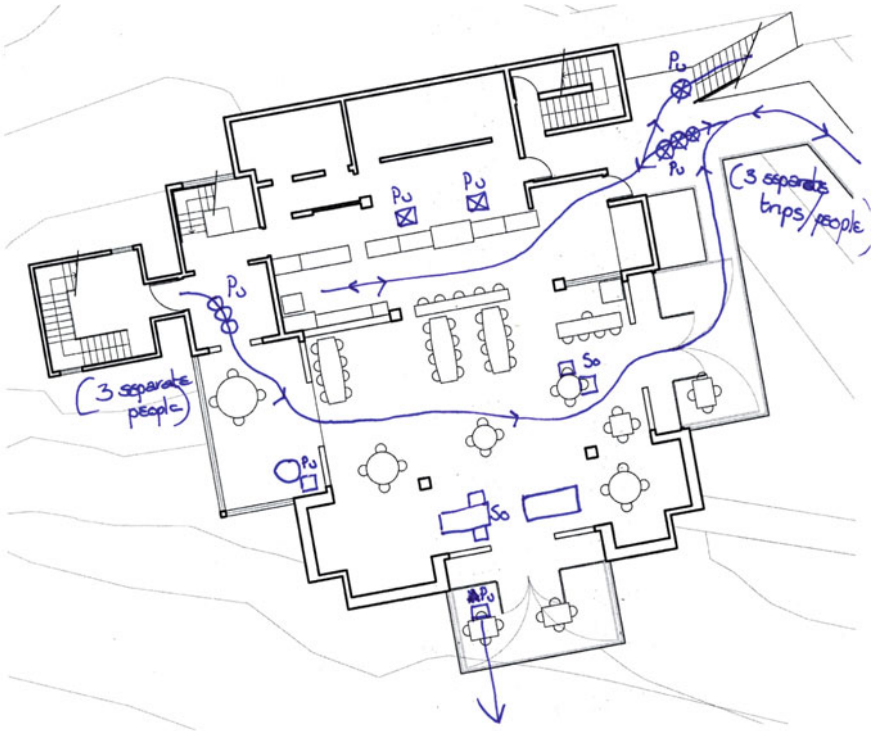
public meetings at Arcosanti where such Intended activities were announced, or by reference to a community notice board which summarised these Intended activities.

The observations also noted any *Visual Interactions with the Natural Environment (V.I.N.E.)* which were occurrences of people displaying behaviour which facilitated viewing the natural environment. Examples of this behaviour included looking out of a window; a person positioning their body and line of sight towards the natural environment; people pointing out features of the natural landscape to other people; people drawing or photographing the natural views (Fig. 4).

Finally there were statistical **Correlations** drawn between the numerical results of the Space Syntax, Nature Syntax, and Observations which showed where there were statistically significant relationships between components. The correlations used *Spearman's rho* (ρ); ± 1 indicated a perfect correlation while 0 indicated no correlation at all: a significance of ≤ 0.1 was termed an S1 significance (weak); a significance of 0.05–0.1 was an S2 significance (moderate); and a ≤ 0.01 an S3 significance (strong).

4 Results from Arcosanti

Table 1 shows the Space Syntax results for the 15 public spaces at Arcosanti, with the Vaults being the most spatially connected (RRA = 0.7523) and Office being the least (RRA = 1.5707). Figure 5 shows the location of all 15 social spaces: they are



Observation Log and Key

Space	CAFE		
Time 5/2/16	Notes (e.g. special event)		
0600-0900			
0900-1200			
1200-1500			
1500-1800 ✓			
1800-2100			
Weather and Temperature (-C)			
SUNNY, WINDY, 8°C			

Interaction Key			Symbol
Interaction with Space, Use of Space	Active	Intended	☒
		Spontaneous	☐
	Passive (and route)	Intended	⊗
		Spontaneous	○
Interaction with Others	Alone		A
	Intimate		In
	Personal		Pe
	Social		So
	Public		Pu
	VINE		→

Fig. 4 Example of completed observation worksheet

distributed across 5 levels, with Level 0 being the ground level. Table 2 shows the Nature Syntax results: the East Crescent roof had the highest visual connection to Nature (VN = 0.64) and the Community Room and Library/Recreation Room both had no visual connection to Nature at all. Table 3 then shows where statistically significant correlations were found across all measured components. There are clearly many points for discussion, but as this paper is interested in how the

Space/Nature Syntax can inform design to facilitate social interaction it will focus on where the results are revealing influences on certain types of social interaction at Arcosanti.

At this point it must be emphasised that correlations indicate only a statistical relationship between components, and not a "cause-and-effect" relationship: the psychological element to be subsequently discussed would give insight on why the relationships exist. There was an S3 correlation between RRA and both Passive Interaction with Space and Spontaneous Use of Space ($\rho = -0.617$ and $\rho = -0.623$ respectively).[1] There was also an S3 correlation between Passive and Spontaneous, with a near-perfect $\rho = 0.963$, indicating that Passive Interaction is highly likely to be unplanned.

Interestingly, there was also an S2 correlation between RRA and Intimate Interaction with Others ($\rho = -0.565$). This indicates that Intimate Interaction is more likely to occur in spaces which are spatially central and experience a high level of movement of people: through-routes. This is surprising, as it was previously indicated that Intimate Interaction is considered the most private of Interactions therefore it would have been expected that this correlation was negative. Intimate Interaction was also correlated with VN ($\rho = 0.508$, S2 strength), indicating that spaces with high visibility of Nature are more likely to see Intimate Interaction. The VN value also, unsurprisingly, returned a correlation with V.I.N.E. ($\rho = 0.494$, S1) indicating that public spaces with high visual connection to the natural environment were more likely to witness people making use of this connection.

In addition to the Interactions returning statistically significant correlations with RRA and VN, there were also interesting correlations among the Interactions themselves which indicates where certain Interactions compliment or discourage each other. The near perfect correlation between Passive and Spontaneous has already been discussed: there were also positive correlations between Active and Passive Interaction with Space ($\rho = 0.533$, S2), and Intended and Spontaneous Use of Space ($\rho = 0.444$, S1). Both these correlations were surprising as they are each other's opposites, in a manner of speaking, therefore any correlation between them would have been expected to be negative. However the positive correlation indicates that a space that is likely to be used in an Active and Intended manner would also be likely to be used in a Passive and Spontaneous manner, suggesting that these opposites are actually encouraging each other.

The only Interaction which returned negative correlations with other Interactions was Alone, which negatively correlated to both Personal and Social Interactions with Others ($\rho = -0.471$, S1 and $\rho = -0.442$, S1 respectively). This suggests that when people are using a space Alone it serves as a deterrent for others to enter that

[1]The RRA value is an inversed value: as spatial connectivity improves, the RRA value reduces numerically. Therefore the negative correlation here indicates that as RRA decreases (and thus spatial connectivity increases) Passive Interaction increases. This should be noted throughout the paper: a negative correlation with the RRA value actually indicates an increase in both factors being discussed.

Table 1 Space syntax results

Public space		TD	MD	C	RA	RRA	IV
14	Vaults	1125	5.0	0.17	0.0354	0.7523	1.3292
6	Community room	1161	5.1	0.20	0.0368	0.7824	1.2780
8	Library/Rec room	1367	6.0	0.50	0.0449	0.9548	1.0473
1	Amphitheatre seating	1403	6.2	0.17	0.0463	0.9850	1.0153
4	Ceramics	1519	6.7	0.33	0.0509	1.0820	0.9242
13	Sky theatre	1522	6.7	0.50	0.0510	1.0845	0.9220
15	Vaults roof	1580	7.0	0.50	0.0533	1.1331	0.8826
12	Roof patio	1587	7.0	0.33	0.0535	1.1389	0.8780
2	Amphitheatre stage	1664	7.4	0.20	0.0566	1.2034	0.8310
3	Cafe	1676	7.4	0.20	0.0570	1.2134	0.8241
9	Music centre	1684	7.5	0.33	0.0573	1.2201	0.8196
7	East crescent roof	1771	7.8	1.00	0.0608	1.2929	0.7734
5	Classroom	1828	8.1	1.00	0.0630	1.3406	0.7459
11	Red room	2063	9.1	0.33	0.0723	1.5373	0.6505
10	Office	2103	9.3	0.25	0.0738	1.5707	0.6366
Mean		1604	7.1	0.40	0.0542	1.1528	0.9039
Median		1587	7.0	0.33	0.0535	1.1389	0.8780

space. Similarly, it could be that people who seek to be Alone do not enter spaces that are already being used by other people. While it is not possible to definitively say which of these is more accurate, both speak to the issue of privacy and an acknowledgement of the need for it at Arcosanti.

Finally, Personal was the only Interaction to have a statistically significant correlation to V.I.N.E. ($\rho = 0.492$, S1), indicating that people who are enjoying the visual relationship to the natural environment from within a built space are more likely to be doing so with people they are comfortable interacting at the Personal distance with, shedding insight on the relationships between people who participate in this activity together at Arcosanti.

4.1 Informing Design Through the Space/Nature Syntax

By establishing the statistically significant correlations it was possible to explore how future alterations to spatial configuration and visibility of Nature at Arcosanti could alter existing patterns of social interaction. Figure 6 shows a future stage of planned construction at Arcosanti named in this research as Phase 3, with significant expansion to the west and south. This construction would significantly change RRA and VN values: Tables 4 and 5 show these values if the construction was completed as planned.

Fig. 5 Location on site of Arcosanti's 15 public spaces

Table 2 Nature syntax results

Public space		P	NoV	VN
7	East crescent roof	0.92	0.59	**0.54**
15	Vaults roof	1.00	0.49	**0.49**
13	Sky theatre	0.96	0.3S	**0.36**
12	Roof patio	0.92	0.40	**0.36**
4	Ceramics	0.63	0.34	**0.21**
1	Amphitheatre seating	1.00	0.20	**0.20**
14	Vaults	0.47	0.36	**0.17**
2	Amphitheatre stage	0.54	0.20	**0.11**
3	Cafe	0.20	0.45	**0.09**
9	Music centre	0.23	0.36	**0.08**
11	Red room	0.16	0.38	**0.06**
10	Office	0.14	0.42	**0.06**
5	Classroom	0.12	0.12	**0.01**
6	Community room	0.11	0.00	**0.00**
8	Library/Rec room	0.00	0.00	**0.00**
Mean		0.49	0.31	**0.18**
Median		0.47	0.36	**0.11**

Figure 7 shows the changes in the distribution of Intimate interaction across Arcosanti's public spaces, and how it could change as a result of the proposed construction. Currently on the site 28.2% of all Intimate interaction is observed in the Vaults. However, as Intimate Interaction was correlated to both RRA and VN and as both would reduce in the Vaults, this share would reduce to 7.7%, a reduction of over 20%. Meanwhile the share of Intimate Interaction in the Cafe increases as its RRA increases: previously it had no Intimate Interaction at all but is projected to have 9.2% of total due to this space becoming a "gateway" to the new construction on the west of the site.

Projected values such as these, derived from statistically significant correlations, could be used to analyse the potential impact of design proposals on social interaction. If the function or atmosphere of a public space was such that a high increase in Passive Interaction, Spontaneous Use, or Intimate Interaction were desired, designers could alter the placement of new construction to increase the spatial centrality of that public space; or they could increase the permeability of the façade through opening size and placement, in a direction where a more natural view lies beyond, if they wished to further increase Intimate interaction. By understanding the indicators of what influences certain types of social interaction, and through understanding that the spatial configuration is not always the sole or strongest influencing factor, public space planners can make informed design decisions to provide spaces that truly meet the spectrum of human social needs.

Table 3 Correlations

		RRA	VN	Active	Passive	Alone	Intimate	Personal	Social	Public	Intended	Spontaneous	V.I.N.E
Spatial connectivity	RRA	1.000											
Visual connectivity to nature	VN	−0.064	1.000										
Interaction with space	Active	−0.129	0.052	1.000									
	Passive	**−0.617*****	−0.112	**0.533****	1.000								
	Alone	0.052	−0.226	−0.376	−0.022	1.000							
	Intimate	**−0.565****	**0.508****	0.432	0.279	−0.107	1.000						
Interaction with others	Personal	−0.292	0.180	**0.795*****	0.334	**−0.471***	**0.514****	1.000					
	Social	−0.295	−0.024	**0.934*****	**0.654*****	**−0.442***	0.418	**0.792*****	1.000				
	Public	0.122	−0.562	**0.723*****	0.252	−0.251	0.070	0.372	**0.643*****	1.000			
Use of space	Intended	−0.186	−0.079	**0.960*****	**0.574****	−0.342	0.391	**0.799*****	**0.897*****	**0.671*****	1.000		
	Spontaneous	**−0.623*****	0.012	0.436	**0.963*****	0.005	0.296	0.282	**0.562****	0.142	**0.444***	1.000	
Visual interaction with the natural environment		0.083	**0.494***	0.217	−0.076	−0.404	0.105	**0.492***	0.157	−0.006	0.187	−0.062	1.000

* $p < 0.1$
** $p < 0.05$
*** $p < 0.01$

Fig. 6 Arcosanti site plan following future proposed construction

Table 4 Space syntax results following proposed construction

Public space		TD	MD	C	RA	RRA	IV
4	Ceramics	5298	6.5	0.33	0.0136	0.5032	1.9871
6	Community room	6015	7.4	0.20	0.0158	0.5837	1.7132
3	Cafe	6074	7.5	0.20	0.0159	0.5903	1.6940
15	Vault roof	6574	8.1	0.50	0.0175	0.6464	1.5470
12	Roof patio	7454	9.2	0.33	0.0201	0.7452	1.3420
14	Vaults	7525	9.3	0.17	0.0203	0.7531	1.3278
8	Library/Rec room	7721	9.5	0.50	0.0209	0.7751	1.2901
9	Music centre	8341	10.3	0.33	0.0228	0.8447	1.1839
2	Amphitheatre stage	8796	10.8	0.20	0.0242	0.8957	1.1164
13	Sky theatre	9029	11.1	0.50	0.0249	0.9219	1.0847
1	Amphitheatre seating	9134	11.2	0.17	0.0252	0.9337	1.0710
11	Red room	10,168	12.5	0.33	0.0283	1.0497	0.9527
10	Office	11,026	13.6	0.25	0.0309	1.1460	0.8726
5	Classroom	11,326	13.9	1.00	0.0319	1.1796	0.8477
7	East crescent roof[a]	n/a	n/a	n/a	n/a	n/a	n/a
Mean		8271	10.2	0.37	0.0226	0.8369	1.2697
Median		8341	10.3	0.33	0.0228	0.8447	1.1839

[a]Existing public space removed by construction

Table 5 Nature Syntax Results following proposed construction

Public space		P	NoV	VN
15	Vaults roof	1.00	0.49	**0.49**
13	Sky theatre	0.96	0.35	**0.34**
12	Roof patio	0.92	0.36	**0.33**
14	Vaults	0.47	0.30	**0.14**
4	Ceramics	0.63	0.20	**0.13**
3	Cafe	0.20	0.42	**0.08**
10	Office	0.14	0.30	**0.04**
11	Red room	0.16	0.25	**0.04**
5	Classroom	0.12	0.12	**0.01**
1	Amphitheatre seating	0.80	0.00	**0.00**
2	Amphitheatre stage	0.46	0.00	**0.00**
6	Community room	0.11	0.00	**0.00**
8	Library/Rec room	0.00	0.00	**0.00**
9	Music centre	0.23	0.00	**0.00**
7	East crescent roof[a]	n/a	n/a	**n/a**
Mean		0.43	0.19	**0.11**
Median		0.25	0.20	**0.04**

[a]Existing public space removed by construction

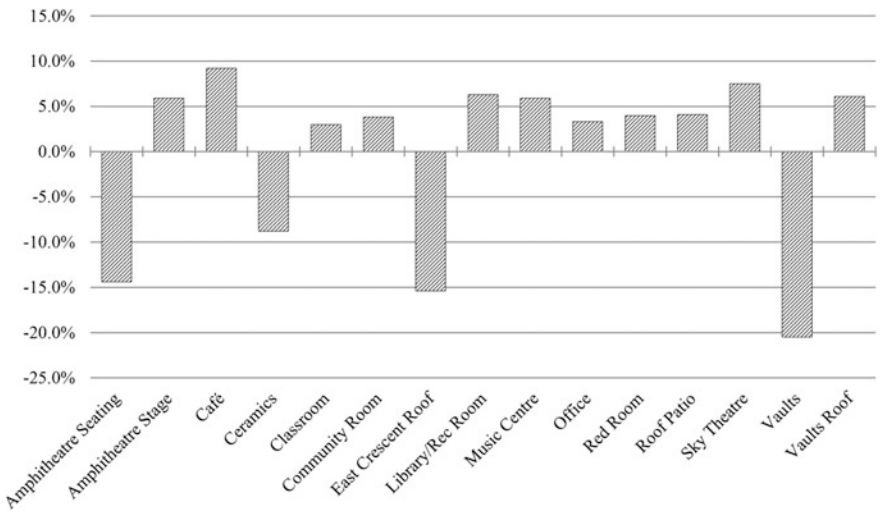


Fig. 7 Projected alterations to distribution of "Intimate" Interaction following proposed construction

5 Discussion

There are some interesting similarities and differences between common observations of how people use public spaces and the results from Arcosanti. The first was the correlation between RRA, and both Passive and Spontaneous. The relationship between spatial connectivity and unplanned, through-route movement in public space has long been recognised: it is both logical and extremely common, and forms some of the most basic principles of Space Syntax studies:

> Let us turn to the factors that make for such places. The most basic one is so obvious it is often overlooked: people. To draw them, a space should tap a strong flow of them. (Whyte 2011 p. 513)

This relationship can also be witnessed at Arcosanti, where the spaces with strong RRA have high Passive and Spontaneous Interaction, as confirmed by the presence of a statistically significant correlation between them. The presence of this most basic relationship between people and space was not unexpected but was useful to evidence, as it speaks to how Arcosanti performs as a built environment, suggesting that even the small dense built environment present there generates the most common patterns of public space use. However what was more unexpected was the correlation between RRA and Intimate Interaction. In the study of Proxemics it is said that Intimate "…is considered improper for the public places" (Agnus 2012). Yet Intimate Interaction was most commonly seen in the most central public spaces at Arcosanti, mirroring the findings of Whyte when studying interactions in public space:

> Lovers are to be found on plazas, but not where you would expect them. When we first started interviewing, people would tell us to be sure to see the lovers in the rear places. But they weren't usually there. They would be out front. (Whyte 2011 p. 513)

There was also a correlation between VN and Intimate Interaction which raises the possibility that this factor, a view of nature, has an influence over social interaction and causes people to behave inversely to social norms, and is more influential than spatial connectivity. While it is not possible to explore this further through statistics alone, it is an interesting point of consideration for the explanation of this common observation, repeatedly stated to go against what one would expect to find.

Another common observation was of Active and Passive Interaction with Space, and Intended and Spontaneous Use of Space being statistically linked. While these Interactions are not complete opposites, it was expected that they would not have a relationship strong enough to result in a statistically significant correlation. However upon reflection on patterns of public space use, it became clear that these are logical correlations. There is a recurring theme that "people attract people" or "Interaction attracts Interaction", with Jacobs, Gehl, and Whyte all observing this fact (Jacobs 2011). Therefore, these relationships further consolidate Arcosanti's public spaces and built environment as performing in a similar way to a traditional built environment.

> Very freely interpreted, a social activity takes place every time two people are together in the same space…The actual meeting, merely being present, is furthermore the seed for other, more comprehensive forms of social activity (Gehl 2011 p. 533)

Despite many commonalities between observed behaviour at Arcosanti and previously observed behaviour in urban environments, there were a few correlations which did not match established patterns. The most significant of these was that Alone negatively correlated to Personal and Social Interactions with Others. This research concluded that, at Arcosanti, people already present in a space partaking in Interactions at the Personal and Social classifications were likely to deter someone who wished to be Alone—or vice versa. This is contrary to what is common in public space literature:

> If you are alone, a lively place can be the best place to be (Whyte 2011 p. 513)

As with the link between Intimate and VN, it is not currently possible to explain why this occurs but it is clear that, at Arcosanti, this relationship between types of Interactions is the inverse of what is commonly observed in public space use.

An interesting relationship which provided to be statistically significant was that between Personal Interaction with Others and V.I.N.E. This correlation suggests the type of relationship between people who were observed displaying signs of V.I.N.E. together. Personal Interaction is the distance at which people interact with close family and friends: this correlation suggests that interaction with Nature is something people at Arcosanti do with people they have this relationship with. This was an interesting finding because of the duality discussed in the Human-Nature relationship studies. Some studies portrayed interaction with Nature as an activity people take part in when they wished to be alone, where other studies found people went to spend time in Nature as more of a social activity. This correlation contributes to this discussion, suggesting that where people are interacting with both other people and Nature at the same time, it is with people that they have a specific close emotional relationship to. Crucially, there was no correlation between Alone and V.I.N.E., suggesting that at Arcosanti at least enjoying a view of Nature is a social activity and not an activity for solitude.

6 Conclusions, Limitations, and Implications for Future Research

As a novel methodology the Space/Nature Syntax naturally experiences some shortcomings. It currently considers only the visual experience of Nature from built spaces. As a methodology which strives to establish the human experience of Nature in urban environments, the Space/Nature Syntax should be developed to consider the entire sensorial range, for example how the sounds, smells and climate associated with Nature are experienced in built space. Secondly, this research is restricted by the use of only one case study in Arcosanti, and would benefit from

repeat studies at different sites to underpin and enhance both the results presented here and the methodology itself. This would allow it to be developed to be fully applicable to traditional urban environments which do not have such extreme access to the natural environment as Arcosanti does. Finally the Space/Nature Syntax would benefit from a component which evaluates the psychological responses of simultaneously experiencing built and natural environments: the work here presents statistically significant relationships on "how" people use space but an element which explores the "why" would clarify and support the findings. This research carried out preliminary work on this and would seek to include the Connectedness to Nature (CtN) methods used in environmental psychology studies.

Despite these limitations the findings of the Space/Nature Syntax at Arcosanti provide a unique insight into how life at the very boundary of built and natural environment impacts people who interact in the public spaces there. This work reveals that both VN and RRA have roles to play in influencing how social interactions occur, and that the two measures may inform different types of social interactions. The projected Interaction figures demonstrate how design proposals could be tested to establish how they could alter relationships between public spaces, relationships to the natural environment, altering how people relate to and interact with others within them. However, it is important to again note that correlations do not show cause-and-effect, merely the existence of a statistical relationship. Thus it cannot be categorically said that, for example, an improvement in RRA definitely causes an increase in Passive Interaction; only that a relationship exists between them. It is imperative that future work supports the statistical data with qualitative evidence as to how spatial connectivity and visibility of Nature affect how people interact.

This work has confirmed patterns such as that between Intimate Interaction and strong spatial connectivity which is common yet counter-intuitive, and set a solid base for further research. Additionally, it has revealed a relationship between Personal Interaction and V.I.N.E. which goes towards clarifying the duality in the relationship between social interaction and the natural environment. While the statistical approach used restricts us from making definitive statements about cause-and-effect, the work has been an essential step; research can now move towards understanding what it is about experiencing spatial and natural connectivity that influences social Interaction.

The Industrial Revolution marked the beginning of an urbanisation that, 200 years later, shows no sign of reversing. Urbanisation is exponential, uncontrollable, and inevitable. The biophilic connection is beneficial, innate, and essential. If the new human landscape is to be urban, then the two must coexist in order for cities to fulfil the biological, emotional, and cognitive needs of humans in addition to the social, political, cultural and economic needs that cities are currently designed to meet. It is through design that the Biophilia connection can be integrated into the urban fabric. But this design must be informed, it must be undertaken with the needs of the human in mind, and must address all of these needs—the biological included. The Space/Nature Syntax takes vital steps towards addressing the need and opportunity to understand how built environments can be designed to nourish humanity's biological need for proximity to Nature.

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