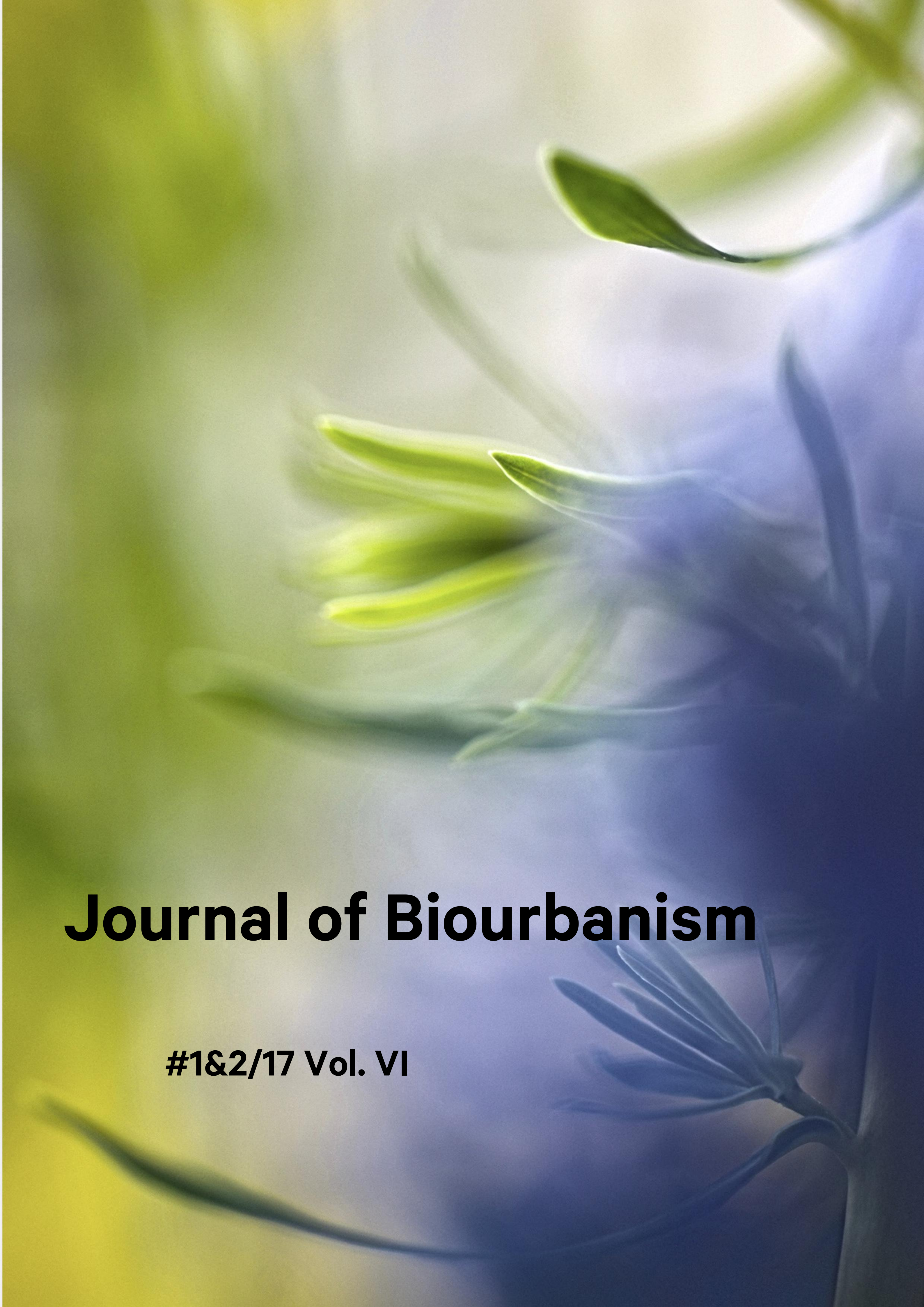

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The **Journal of Biourbanism JBU** is a biannual peer-reviewed, interdisciplinary, international online journal. The journal takes an incisive look into the bios/life of urbanism through perspectives in architecture, planning, environmental studies, and other social sciences. The journal aims to critically review and define the notions of biourbanism. Assessing human-centered or need-based design sensibilities is a predominant concern, while attempting to address the disconnect between theory and practice in participating disciplines. The journal publishes cutting-edge research, methodologies, and innovative design approaches on biourbanism.

CONTENTS

EDITOR’S NOTE 7
Antonio Caperna

CONNECTING WITH NATURE 9
BIOPHILIC DESIGN IN ENVIRONMENTS BUILT FOR COMMUNAL LIVING
Carol Price & Gary Skolits

THE IMPLICATIONS OF FRACTAL FLUENCY FOR BIOPHILIC ARCHITECTURE 23
Richard P. Taylor, Arthur W. Juliani, Alexander J. Bies, Cooper R. Boydston,
Branka Spehar, & Margaret E. Sereno

HUMAN-NATURE INTERACTION PATTERNS 41
CONSTITUENTS OF A NATURE LANGUAGE FOR ENVIRONMENTAL SUSTAINABILITY
Peter H. Kahn, Jr., Elizabeth M. Lev, Sara Park Perrins, Thea Weiss, Trecia Ehrlich,
& Daniel S. Feinberg

A PSYCHOLOGICAL APPROACH TO OLFACTORY INFORMATION AS CUES IN OUR ENVIRONMENT 59
Kai Hamburger & Harun Karimpur

RELATIONSHIP BETWEEN URBAN MORPHOLOGY AND PATIO HOUSING 75
IN MEDITERRANEAN EUROPEAN CITIES DURING THE XV–XVI CENTURIES
Valentina Pica

THE PROMISE AND THE LIMITS OF BIOPHILIC ARCHITECTURE 93
Paul Downton

BUILDING A CONCEPTUAL FRAMEWORK FOR SMARTING AN EXISTING CITY IN MAURITIUS 103
THE CASE OF PORT LOUIS
Zaheer Allam

DISCUSSIONS & REVIEWS

KAIDE [PLINTH] 125
Sara Bissen

SMALL URBANISM FOR EVOLVING CITIES AND THEIR PARTS 128
Amy Tibbels

#1&2/17

Editor's Note

Antonio Caperna
Editor in Chief, International Society of Biourbanism, Italy

In 1984, Edward O. Wilson's book *Biophilia* introduced the hypothesis that humans possess an innate tendency to seek connections with nature and living beings. Since then, many studies have been published about the role of natural structures on our mental development and neuro-physical well-being. The role and influence of nature and natural forms on humans opened new and interesting scenarios centered on biology and evolutionary processes. One of the emergent fields has been the role of biophilia in design, and more generally, in the built environment. Much research has focused on this topic and aimed at ameliorating the quality of the city, including our daily aesthetic and cognitive experience of it.

After analyzing the literature, I have come to believe that there is still much work to do in answering specific questions. What is the deep meaning of biophilia? How can we recognize real biophilic design beyond the use of plants and green infrastructure? Why do ancient built environments seem more "biophilic" than most modern constructions? Finally, should we not address the political and economic structure of our society if we want to make our world "biophilic"?

These and other questions should guide our research for building a better environment. Too many architects and planners have reduced biophilia to a mere "green approach" where green infrastructure is presented as the panacea to solve every problem of contemporary cities. Consequently, architects and planners vow to fill cities with plants, green façades, roofs, et cetera. Such a childish approach marks the gap from real biophilic design. The use of vegetation is nothing but a small piece of biophilia, as European cities abundantly show with the limited support of patios and small gardens. Their successful design comes rather from the enforcement of rules, which provide a connection between the built environment and the purposes of the community. They constitute a bridge on which ancient masters have built a living architecture.

Biourbanism stresses the relevance of biophilic design in connecting and strengthening life to support people's cognitive, social, and psychological needs in space.

Biophilic architecture should thus be characterized by three attributes: 1) a naturalistic dimension; 2) wholeness of the site, and 3) geometric coherency. All of these attributes reinforce social interaction by supporting the unfolding of inclusive environments that reflect the inborn affinity between human being and nature, and at the same time, are capable of supporting our neuro-physiological, psychological, and biological systems.

This current issue of the *Journal of Biourbanism* is dedicated to biophilia and design.

In "Connecting with Nature: Biophilic Design in Environments Built for Communal Living", Carol Price and Gary Skolits examine the role of biophilic design in developing therapeutic landscapes and restorative spaces. This works enriches the therapeutic landscaping literature with a focus on people who have been diagnosed Alzheimer's and dementia.

The second contribution entitled "Human-Nature Interaction Patterns: Constituents of a Nature Language for Environmental Sustainability" by Peter H. Kahn, Elizabeth M. Lev, Sara Park Perrins, Thea Weiss, Trecia Ehrlich, and Daniel S. Feinberg, analyzes interaction patterns. The Authors suggest that saving nature is not enough of a step. Humans should interact more with nature, and interaction pattern design can help reach such a goal. To illustrate this notion, they discuss over 60 interaction patterns to expand the idea of biophilic design in supporting environmental sustainability.

In "A Psychological Approach to Olfactory Information as Cues in Our Environment", Kai Hamburger and Harun Karimpur discuss how olfactory information can facilitate our landmark-based spatial orientation. The Authors show how sensorial support may be very useful in nursing homes and clinics. Scents, as an attribute of biophilic design, can enhance cognitive abilities and quality of life.

The contribution "Relationship between Urban Morphology and Patio Housing in Mediterranean European Cities during the XV–XVI centuries" by Valentina Pica investigates the use of the typological model of the patio house and its relation with the urban form in Mediterranean Europe during the 15^{th}–16^{th} centuries. Pica analyzes the construction phases of more than 20 traditional houses in the historic center of Granada, Spain. Her study is linked to several analyses that focus on traditional architecture and the role of the *medina* in the Islamic West.

The work of Paul Downton, "The Promise and the Limits of Biophilic Architecture", proposes the combination of biophilia as a way to support human health and biourbanism as an approach to support urban life in all its forms. The Author also suggests that the limits of biophilic design are not strictly dependent on biophilic sensibilities, but rather on valuing nature for its intrinsic worthiness.

"The Implications of Fractal Fluency for Biophilic Architecture" by Richard P. Taylor, Arthur W. Juliani, Alexander J. Bies, Cooper R. Boydston, Branka Spehar, and Margaret E. Sereno discusses how fractal forms interact with the human visual system. The Authors analyze how fractal art and architecture facilitate navigation. The visual effect of fractal patterns generates an aesthetic experience accompanied by stress mitigation.

Finally, the contribution by Zaheer Allam "Smarting an Existing City in Mauritius: The Case of Port Louis", proposes an ecologically sound approach to the "smartization" of the capital city of Mauritius as an extension of biophilia into urban-scale service design.

The biophilic approach is a turning point for design. Next, biourbanism studies should address the realization of a coherent framework able to extend and transform this corpus of observations, laws, and principles into a set of practical design and building tools.

Connecting with Nature: Biophilic Design in Environments Built for Communal Living

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ABSTRACT

Biophilic design in the conceptualization and interior design elements of indoor and outdoor communal and group living spaces can be especially advantageous to those who dwell in and use these spaces on a daily basis. This concept borrows heavily from architectural design considerations for built structures in nature centers, i.e., outdoor spaces reserved specifically for experiencing nature in communal settings. The nature center designs reflect their natural surroundings in a manner that increases levels of interest and engagement by visitors to the centers. Therapeutic landscaping, based on Biophilic design concepts, has been demonstrated by scientific research and anecdotal evidence to benefit residents of assisted living centers and long-term care facilities, particularly residents who have been diagnosed with Alzheimer's and dementia. This paper examines the relatedness of Biophilic design to theories in therapeutic landscaping and restorative spaces/healing places, connecting the dots between therapeutic landscaping and Biophilic design concepts in built environments.

Keywords: biophilic design; nature centers; therapeutic horticulture; therapeutic landscaping; restorative/healing places; Alzheimer's disease; dementia; assisted living centers; indoor group living spaces; built environments; ecopsychology; supportive design theory

INTRODUCTION

The integration of biophilic design elements and principles within a built interior can create or enhance a positive and soothing environment throughout the installation of features that echo the natural world. According to DeGroff & Wood (2016) and Jo, Rodiek, Fujii, Miyazaki, Park, & Ann (2013), human affinity for the elements and principles found in nature remains active for individuals who have been diagnosed with dementia and Alzheimer's disease. Incorporating this basic connection with nature into design decisions can improve the human experience. Further, utilization of the human-nature connection, as a structure or model reflecting how we interact with our natural environment, can enhance our experiences within the built environment. Opportunities to connect our natural affinity with nature can be achieved indoors as well as outdoors, usually through the offering of sensory stimulation from, or interactive participation with, natural elements. In this discussion, "nature" is defined as elements occurring in the natural world, consistent with definitions employed by Kellert & Calabrese (2015) and Gibson, Chalfont, Clark, Torrington, & Sixsmith, (2008), such as plants and animals; air, land, water, and sky; rain, sun, stars, wind, and snow.

Incorporating elements of nature into the interior design features of communal and group living spaces can offer benefits reflective of therapeutic landscaping and healing gardens as design elements, bringing the outdoors and nature inside (Ulrich, 1984; Jo et al., 2013). Elements of nature featured inside assisted living spaces can subtly increase involvement and engagement of the residents, especially those who have been diagnosed with dementia or Alzheimer's disease (Ulrich, 1984; Jo et al., 2013). Elings (2006) found that "Studies with Alzheimer patients showed that physical exercise can improve the cognitive abilities. Specifically designed gardens can be a source of sensory stimulation for Alzheimer patients in terms of color, smell and texture, and can stimulate emotion and positive feelings and memories" (p. 49). Further, continuous exposure to natural elements through biophilic design—such as living plants, a window with a view of grass and trees, regular or occasional interactions with companion animals, exposure to the sounds of birds and the rain, or seeing snow falling and drifting—can increase activity levels for this population of residents (Ulrich, 1984; Gibson, Chalfont, Clark, Torrington, & Sixsmith, 2008).

The primary goal of this paper is to examine biophilic design as a beneficial design concept in built environments designated as residential facilities for persons diagnosed with dementia or Alzheimer's disease. In aid of that objective, discussion is included concerning the relatedness of biophilic design to other theories, particularly, therapeutic landscaping and horticulture therapy; restorative spaces/healing places; and bringing the outside inside—edge-space concept. The discussion also addresses the application of biophilic design considerations in other communal built environments, such as nature centers. Finally, to comprehensively inform this investigation of biophilic design in built environments, both quantitative and qualitative research methodologies were examined in the review of literature. The conceptualization of this inquiry is largely based on personal observations by the senior Author, capturing the emotive and experiential responses of a family member and those of other residents, to stimuli embracing biophilic design elements in two assistant living facilities.

Characteristics of biophilic design in communal settings include plants, animals, water, and views of grass and trees, as well as the activities and processes related to involvement in gardening activities (hands in the dirt!) (Kellert & Calabrese, 2015). As a concept, biophilic design is an outgrowth of healing gardens and the concept of bringing the outside inside and related practical applications to enhancing the lives of residents in assisted living facilities (Kellert & Calabrese, 2015; Ulrich, 1984; Haubenhofer, Eilings, Hassink, & Hine, 2010). According to Ulrich (1999) and Rodiek (2002), health outcome research can demonstrate the medically beneficial results of having gardens in health care environments. For instance, benefits can include "reduction in stress and anxiety, reduction of depression, higher quality of life, reduced pain," plus "reduced provider costs, increased patient mobility and independence, and higher patient satisfaction" (Ulrich, 1999, p. 74). The positive benefit of gardens in healthcare environments, such as assisted living settings, has been recognized by the healthcare industry (Cooper-Marcus, 2007; Rodiek, 2002), although the issue of the degree of benefit versus cost-effectiveness of a garden remains under investigation. Application of this concept is supported by theoretical approaches, such as restorative spaces/healing places, therapeutic horticulture/landscaping, and the concept of edge space.

According to the research (D'Andrea, Batavia, & Saason, 2008; Rodiek, 2002; Gonzalez & Kirkevold, 2014), persons diagnosed with Alzheimer's type of dementia benefit from horticultural therapy activities. Horticulture therapy incorporates the activities involving planting and growing plants as planned programs, using plants, gardens, and other aspects of nature, executed as part of a formal plan with hands-on involvement (D'Andrea, Batavia, & Saason, 2008; Gonzalez & Kirkevold, 2014). The practice of horticultural therapy may be referred to as therapeutic horticulture, garden therapy social horticulture, and therapeutic gardening with the terms used interchangeably. According to the American Horticultural Therapy Association (2017), the distinctions among these terms are important for professional certifications, but in practice, the terms refer to human interaction with plants and gardens. Healing gardens provide opportunities for visitors to passively and/or actively engage their senses, i.e., hearing, seeing, smelling, and touching (Smith, 2007; Haubenhofer, Eilings, Hassink, & Hine, 2010). "The primary focus is to regain wellness in one or more of the three dimensions of existence: physical, psychological, spiritual. The effect to the user should be life-affirming" (Smith, 2007, p. 10).

According to Noone and colleagues (Noone, Innes, Kelly, & Mayers, 2015) and Rodiek (2002), incorporating horticultural therapy activities in the holistic care of persons diagnosed with dementia is under-utilized. This approach to working with residents in care environments has been demonstrated by the research to be effective (Noone, Innes, Kelly, & Mayers, 2015; Rodiek, 2002; Chalfont & Rodiek, 2005), improving the wellbeing of this segment of the care population both physiologically and psychologically. Gardening can be a pleasurable activity if the garden is designed to invite participation by persons diagnosed with dementia or Alzheimer's disease (Noone, Innes, Kelly, & Mayers, 2015; Rodiek, 2002). Such a garden would be designed to accommodate participants with both cognitive and physical challenges. "The cognitive changes experienced by people with dementia, in addition to age related physical impairments, may impact upon their ability to participate in gardening activities, a garden designed in a manner conducive to the needs of people with dementia can provide an enriching therapeutic experience" (Noone, Innes, Kelly, & Mayers, 2015, p. 6). The individual gardening activities can be very satisfying—from planting seeds, watering the plantings, to, ultimately, growing their own food. According to Noone and colleagues (2015) and Gonzalez & Kirkevold (2014), residents participating in horticultural therapy interventions reported a sense of achievement in working in the gardens. Engagement of the senses helped participants to recall memories of gardening earlier in their lives as well as the pleasures of gardening. Participation can trigger memories and sharing those memories often opens the door to more memories (Price, personal communication). Research suggests that horticultural therapy can delay cognitive decline in care home residents diagnosed with Alzheimer's disease (D'Andrea, Batavia, & Saason, 2008; Gonzalez & Kirkevold, 2014). "For people living with dementia in the home, few such opportunities to improve their well-being in a holistic and productive manner are currently available, and the isolation, anxiety and depression experienced by this population is likely to increase as the number of people living with dementia grows" (Noone, Innes, Kelly, & Mayers, 2015, p. 9).

Healing gardens, also characterized as restorative gardens, are designed for specific populations, in a designated place to result in positive health outcomes (Sachs, 2016; Gonzalez & Kirkevold, 2014). Physical design and programming activities are informed by the research and incorporated into the design of healthcare structures, such as hospitals plus assisted living and hospice facilities (Haubenhofer, Eilings, Hassink, & Hine, 2010). The gardens can also be found in city parks, as an added feature in museum grounds, and in shared communal environments, such as a section of a community garden. Passive and active interactions with the garden are by design and can result in stress reduction, reduction of depression, improved quality of life, reduced pain, and improved way-finding in a healthcare facility (Ulrich, 2000; Gonzalez & Kirkevold, 2014; and Haubenhofer, Eilings, Hassink, & Hine, 2010).

Access to nature is one stratagem in Roger Ulrich's Theory of Supportive Design (2000), "giving particular emphasis to stress reducing and other beneficial influences of viewing nature in indoor and outdoor settings" (p. 7). According to Sachs (2016), viewing gardens from indoors, as well as accessing the gardens in the outdoors, is beneficial, throughout each of the seasons. Ulrich (2000) offers several design suggestions to enable access: "nature window views for patient rooms, waiting areas, and staff spaces; a soothing garden that family, patients, staff can easily access for relief from the hospital environment; an aquarium in a high-stress waiting area; an atrium with greenery and a fountain; and calming nature art mounted where bedridden patients can readily see it" (p. 7). Each of these nature venues promote indoor or outdoor biophilic design considerations in built environments designated for persons diagnosed with dementia or Alzheimer's disease.

Specifically regarding communal facilities such as assisted living, Chalfont & Rodiek (2005) noted that research indicates incorporating elements of nature into assisted living facilities can lead to better sleep patterns, improved hormone balance, and decreased agitation and aggressive behavior. In addition, data collected from engagement with residents through case studies indicated that residents' experiences in nature were positive, "their response to gardens and being outdoors was overwhelmingly positive and clearly lifted their spirits" (Chalfont & Rodiek, 2005, p. 343). Bringing the outside inside—the edge-space concept—speaks to the practice of orienting a built environment to the outside, recognizing that at each boundary between the inside and outside environment is an edge—such as where the city ends and the country begins, where the patio ends and the grass begins, or where the beach ends and ocean begins. Those edges can figure very significantly in the design of assisted living facilities offering opportunities for residents to benefit from interactions with natural elements, such as a healing garden in a courtyard, a greenhouse, birds, fresh air, and even rain, wind, and snow (Chalfont, 2009).

In the study on bringing the outside inside, Chalfont and Rodiek (2005, pp. 344–346) suggested three steps to increase nature in the lives of persons diagnosed with dementia:

Step 1 Remind and reawaken a need—"A design must remind us what nature has to offer, entice us, and instill a daily desire to re-experience it." Dementia takes away memory; nature can reawaken the innate connection.

Step 2 Nature, sensation, and emotion: The joy of place—"Nature is a large powerhouse of sensation to step out into—the spiritual, sensual, connection nature uniquely allows.”

Step 3 Nature, not landscaping: Real needs, real places—Engage residents based on their expressed preferences in connecting the outdoor area to the indoor living space. Residents may simply enjoy touching the flowers or sitting and talking about the plantings. Other residents may want to participate in the planting activities.

Restorative spaces and healing places theories are supportive of the healing impact of biophilic design elements in assisted living and communal living facilities (Kaplan, 1995). In his 1984 research, Robert Ulrich initiated the direct connection between nature, health, and healing studying the impact of viewing nature on patients recovering from surgery. In addition, according to Ulrich, Simons, Losito, & Zelson (1991), views of nature by an individual reduced cortisol levels and heart rate, in addition to other positive physiological and psychological effects on seniors. More recently, a comprehensive review of the literature by Gillis & Gatersleben (2015) noted that natural elements—natural light, water, plants, weather, and the view of greenery from a window—are beneficial, contributing to a restorative environment (Pretty, 2004). Further, Martínez-Soto, Gonzales-Santos, Pasaye, and Barrios (2013, p. 10) indicate that incorporating restorative elements into the very design of built environments “can help building occupants to ‘provide’ cognitive and affective resources necessary for adequate human functioning”.

Access to nature is important, having many restorative properties; interactions with the natural world can be calming and inspirational, offering ever changing vistas (Ulrich, 2000; Sachs, 2016). Not only are we innately connected to elements of nature, but we also benefit from that connection physiologically and psychologically (Kaplan, 1995; Rodiek, 2002; Pretty, 2004). Included in the range of benefits are reduced stress, depression, fatigue, and aggression, as well as pain, myopia, and other neurological symptoms. Moreover, interactions with nature can lead to improvements in cognitive functioning and emotional resilience, among other emotional and mental processes (Cooper-Marcus & Sachs, 2014; Kuo, 2015; Ulrich, 1984; Ulrich, Simons, Losito, & Zelson, 1991). Directly bringing green, living nature into the indoor environment, such as placing plants inside, has been demonstrated to benefit the health and wellbeing of residents (Smith, 2007; Pretty, 2004). Moreover, just the viewing of greenery from a window has also been shown to benefit the health and wellbeing of residents (Smith, 2007; Pretty, 2004).

Design considerations for residential and non-residential communal-use structures, such as nature center buildings, are reflective of biophilic design elements (2008, personal communication). In response to a query asking nature center directors “what attracts visitors to your nature center”, several directors cited the building itself, as noted in these shared excerpts (2008, personal communication):

- (nature center) building itself is a draw because of its green design;
- first nature centers with a LEED building as the center—the “greenest” building—functions as a teaching building, influencing building in the state and beyond;
- LEED building—teaching junior high and high school kids, plus offering tours to the public—building itself is a teaching building in addition to using the design to teach;
- the facility—designed to highlight the landform of the location.

Traditionally, scientific research investigations into human responses to external stimuli are restricted to quantitative, measureable data collection, such as neurological responses (Ulrich, 1999). However, when people experiencing cognitive functions compromised by dementia or Alzheimer's disease are involved, employing a qualitative, ethnographic data collection methodology can promote deeper understanding of a "truer" personal story—a story told and experienced from the viewpoint of a close family member sharing the journey with those wh are negotiating their lives with ever diminishing mental capacities. (Chalfont & Rodiek, 2005; Rodiek, 2002). As both quantitative and qualitative methodologies have been utilized in the study of participant responses to the incorporation of biophilic design elements in assisted living facilities, both quantitative and qualitative research methodologies were examined in the review of literature.

Research-based evidence of the impact of nature on individuals diagnosed with dementia and Alzheimer's disease is supported by personal observations as reported below. Ultimately, the stories of participants reflect the realities of their experiences—in captured observed reactions to events. According to Chalfont & Rodiek (2005), what has been lacking in the research has been a focus on observation and reflection in these studies. The Authors believe that by recording participants' own words and capturing observable events in a story format, a more realistic assessment of the true impact of the environment and the event may emerge. Chalfont & Rodiek's (2005) ethnographic approach employing observation and reflection supported the personal observations presented below. These observations are chronicled as experienced by a close family member, presented in a story format and, therefore, more revealing of the resident's experience.

Among the 6 elements and 75 nature-based design attributes identified by Kellert & Calabrese (2015), the biophilic design characteristics most applicable to residents' experiences in the assisted living facilities are direct experiences with water, air, natural light, natural views and vistas, animals, and native plantings, and indirect experiences with planting activities, including potted plants and garden plantings. The degree and variety of residents' involvements with the elements was based on family member's perceived observation of residents' initial reactions and follow-up engagements.

BIOPHILIC DESIGN ISSUES IN TWO ASSISTED LIVING FACILITIES AND A FAMILY MEMBER'S REFLECTIONS OF RESIDENT REACTIONS

Joy, the mother of the senior Author of this paper, was diagnosed with Alzheimer's disease in her late seventies. The everyday visual signs of nature—sunshine, birds, raindrops, butterflies, blooming plants, or leaves falling from trees—all had meaning during my mother's active life. She was an inveterate gardener and lived in tune with the seasons. Nature remained significant and an ever-present factor as we negotiated her way through the increasingly complicated world into which she was transported due to diminished capacity.

Approximately two years into her Alzheimer's disease experience, Joy was relocated from her own home to an apartment in an assisted living facility. Selection of the facility was based on three factors extraneous to price, care ratio, and other daily living amenities. Most important were the acceptance of Kitty Cat, her companion animal, windows in every room that provided broad views of an enclosed courtyard, the freedom to incorporate aspects of the natural world into her personal living space, and a sunroom built into the design of the facility. During the final 14 months of Joy's life, I found that she related to the elements of nature incorporated inside the built environment, as viewed from her window and experienced in her personal living space, and outside in the enclosed courtyard and during our daily drives in the local neighborhoods.

In addition, other residents of the facility responded regularly and enthusiastically to natural elements introduced into the interior of the building and the enclosed exterior courtyard, effectively bringing the outside inside. For example, a story-board on the wall next to Joy's apartment entry-way which showcased blooming houseplants with accompanying name cards and pictures served as a "meet and greet" spot for residents.

As staff at the facility observed residents' responses to activities in the sunroom, greenhouse, and the other planting activities in the courtyard, projects were undertaken to increase participation and enjoyment. For instance, relatives of the director built a raised bed on site—much to the enjoyment of the residents and their visitors! The area around the raised bed was prepared to accommodate wheelchairs and walkers, insuring the path was smooth and easily navigated by those with physical impairments. Benches were placed strategically around the courtyard, and birdbaths added. In keeping with Ulrich's (2000) suggestions, each resident enjoyed a view of the outdoor environment with blooming plants or a birdbath.

Seeds planted in peat pots in the sunroom were moved to the courtyard raised bed garden with residents remarking on the changes as the plants grew and vegetables began to take shape. One resident, who grew up on a farm and regularly fingered any growing plant, picked green tomatoes from the courtyard raised bed garden, carrying them inside to ripen on her windowsill.

The following reflect personally observed experiences of individuals diagnosed with dementia and Alzheimer's disease experiencing nature in the two residential assisted living facilities:

The sunroom greenhouse

Plants grown in peat pots in the portable greenhouse, ultimately, were relocated to the raised bed garden in the enclosed courtyard. From the beginning, I observed residents and visitors reminiscing about their own experiences in the garden, including planting, growing, and harvesting many, many varieties of crops.

Planting seeds and removing spent blossoms

Joy held seeds in her hand while I, as her helper, placed the seeds in peat pots, which were then placed in a portable greenhouse in the sunroom. For many months, she had been unable to distinguish individual shapes in framed wall hangings or in print; however, when her helper inadvertently dropped a seed on the tweed carpet, Joy quickly pointed out the exact location of the seed by gesturing with her finger. If my response was not immediate, she maintained that posture until I bent down and retrieved the dropped seed. She participated further in our planting activities by holding her hand out to receive spent blossoms removed from pots of petunias and other blooming plants. She would point to spent blossoms remaining on the plant until all were removed.

Plant watering the first ever involvement in an activity since moving into the facility three years prior

I observed a male resident, who just appeared in the sunroom one morning, as he hefted a filled watering can, and began watering every single planted peat pot in the portable greenhouse and the potted plants placed around the room. That task completed to his satisfaction, he then moved out the sunroom door into the courtyard and watered all the plantings in the courtyard. From that day forward, he watered the plantings in the sunroom and courtyard every single day (whether they needed it or not). He set his own schedule, worked out the watering routine and only required (or accepted) assistance filling the watering can and turning the courtyard water spigot on and off. Up to that time, the resident had consistently refused to participate in any facility activities or celebrations. He had been very angry about moving to the facility from his home. His participation in the gardening activities and his control of the watering tasks made a difference in this gentleman's attitude toward the other residents and the staff.

Birds on the wing

I observed Joy watching the activity of the birds from her living room and bedroom windows; she spent time every day in this pursuit. Birds observed in flight were remarked upon with hand gestures simulating the fluttering movement of their wings and flight patterns.

Rain cascading from a rooftop

I observed Joy watching the rain from her living room window as it poured over the drain spouts on the other side of the courtyard. Pointing to the rain spouts, she would make waving gestures with her hand and fingers. She and I would walk to the outside door down the hall, open the door, and then stand on the covered patio to get a different view of the rain. We stayed for the "rain show" until Joy was ready to return to her window view. She indicated she knew it was rain by retrieving her rain bonnet to protect her hair when we walked to the patio door.

Watching a parade of chrysanthemums

My two helpers and I brought a "trove" of potted chrysanthemums into the facility in armloads, requiring multiple trips to a designated display area. The activity room opened off the hallway access to the place designated for the chrysanthemums. Residents were seated in the activity room enjoying their regular game of bingo. Included in the gathering were ambulatory residents, with some in wheelchairs. Almost 30 beautifully blooming chrysanthemums in glowing fall colors were carried down that hallway. By the third trip down the hallway, an audience of about 25 residents who had noticed the "parade" had gathered in the hallway in response to the beauty of the flowers, expressing their appreciation with applause and oohs and aahs.

Sweet potato vines spawn stories of a resident's experiences growing up on a potato farm in Sevier County

Residents present in the gathering room regularly questioned the names of plants I had brought into the facility. When informed that the plant in the pot was a sweet potato vine, one resident began to tell the story of her family's yearly trek to the "big city" to sell the potatoes they had grown on the family farm. For her family, the potato money was critical for buying food and supplies. All the kids worked in the fields, and when the potatoes were loaded for market, the family climbed aboard on top of the potatoes with the kids sleeping during the long drive. Although the potatoes made a very bumpy, lumpy bed upon which to sleep, the kids slept because they had to get up so early to go to market.

Plants in the "gathering room" spark stories of plants grown from seed, vegetables, fruit trees, and birdhouses

Reminiscing and storytelling became the standard as plants were carried through the gathering room to be installed in the courtyard. Residents grouped together at the windows or migrated into the courtyard to oversee our activities. Shared stories included when they planted, how much land they farmed, what vegetables they grew in their gardens, how they cared for fruit trees, and how to build birdhouses. Other residents were engaged touching the leaves and blossoms, repeating the names of plants, or simply talking about the plants. Non-verbal gestures and smiles indicated the pleasure experienced by residents unable to communicate verbally.

The human animal bond remains intact throughout the Alzheimer's disease experience

I observed that companion animals were engaged with residents on a regular basis. Several residents shared their living arrangements with a dog or cat, family members brought animal companions to the facility to visit, and a local organization regularly visited with dogs and cats. Joy's companion animal, Kitty Cat, moved into the facility with her and was a constant companion. Kitty Cat's presence brought a version of comfort beyond that achievable by the human animals involved in my mother's life. On her last day of awareness, she stretched her hand to pet Kitty Cat who was curled up at the foot of her bed. That evening and night, she rested in a medically induced sleep, and died the next day.

CONCLUSION

Biophilic design literature clarifies and strengthens the natural and harmonious relationship between residents and the elements of nature. Findings relevant to the focus of this article indicate:

a) Research supports the presupposition that incorporating elements of nature into interior aspects of assisted living centers will contribute to the health and wellbeing of residents.

b) Evidence suggests that biophilic design attributes result in measurable increases in residents' engagements in activities sponsored by the facility and interactions among residents.

c) Creating a positive and soothing environment is significantly beneficial for residents who have been diagnosed with dementia or Alzheimer's disease.

Here are some especially relevant biophilic design elements for communal spaces that are particularly noteworthy, culled from the literature and reflective of the senior Author's (C.P.) personal experience with her family member:

a) A sunroom accessible to residents and visitors built into the design of the building or incorporated into the campus of the facility.

b) A greenhouse or other growing platform accessible to residents and structured to invite resident participation in planting seeds, nurturing seedlings, watering, caring for the plants, and harvesting fruits or vegetables. Minimal monitoring of the greenhouse by a volunteer provides assistance to residents when needed.

c) Clear views from resident windows providing sights of wild nature or cultivated plantings with season-specific changes in the viewed outdoor landscape.

d) Inside outside *easy* transitions for residents whose interests may be in getting closer to what they can see from the inside. I (C.P.) observed that residents cannot always figure out the difference between a door and a window.

I (C.P.) frequently observed the impact on residents when encountering nature. These observations indicated:

a) Residents of assisted living facilities react to elements of nature encountered inside the built environment in manners that are observable.

b) Those reactions can include facial expressions, such as smiles or opening the eyes very wide; verbal sounds, such as fractured word combinations or structured comments; hand movements; physical responses, such as moving toward the element or interacting with the flowers and/or bushes by touching, fingering, and "petting" the blossoms, leaves, *and* the dirt.

c) Often, a resident's remembrances of past relationships with nature are captured, dependent on the individual's degree of dementia or stage of Alzheimer's disease.

d) Among residents whose verbal abilities have not been impaired, discussions take place that are inclusive with participants engaged actively in exchanging experiences and discussing the "best" or "right" way to plant, grow, harvest, prepare, and cook produce from their gardens.

e) Companion animals add a sense of wellbeing to the everyday lives of residents in assisted living spaces, often fulfilling the role of the "other" in their personal living space. The companion animal can be the catalyst for interactions with other residents or visitors, is a warm presence when the resident returns to his or her own room, and offers complete acceptance and companionship. Awareness of the companion animal can remain active throughout the end of life process.

Nature is of critical importance to people diagnosed with dementia or Alzheimer's disease. Additionally, the issues of controlling behavior and managing risk are acknowledgeably important in the design of assisted living facilities. However, as noted by Chalfont & Rodiek (2005), quality of life for persons diagnosed with dementia or Alzheimer's disease will be enhanced immeasurably by moving to design concepts that focus on "how environments can actively encourage pleasurable and satisfying behavior, for everyone who lives or works within or near them" (p. 347). Biophilic design elements incorporated into assisted living facilities can work that magic.

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The Implications of Fractal Fluency for Biophilic Architecture

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ABSTRACT

Fractals are prevalent throughout natural scenery. Examples include trees, clouds and coastlines. Their repetition of patterns at different size scales generates a rich visual complexity. Fractals with mid-range complexity are prevalent. Consequently, the "fractal fluency" model of the human visual system states that it has adapted to these mid-range fractals through exposure and can process their visual characteristics with relative ease. We first review examples of fractal art and architecture. Then we review fractal fluency and its optimization of observers' capabilities, focusing on our recent experiments which have important practical consequences for architectural design. We describe how people can navigate easily through environments featuring mid-range fractals. Viewing these patterns also generates an aesthetic experience accompanied by a reduction in the observer's physiological stress-levels. These two favorable responses to fractals can be exploited by incorporating these natural patterns into buildings, representing a highly practical example of biophilic design.

Keywords: fractals, biophilia, architecture, stress-reduction, navigation

INTRODUCTION

Due to their prevalence in natural scenery, fractal patterns are a central component of our daily visual experiences. Examples include lightning, clouds, trees, rivers and mountains. Fractals can also be generated artificially. These can be divided into two categories—“exact” and “statistical” fractals. Exact fractals, which are built by repeating a pattern precisely at different magnifications, have been explored by mathematicians since the 1860s. It was not until the 1980s that Benoit Mandelbrot published *The Fractal Geometry of Nature* in which he catalogued and discussed nature’s statistical fractals, using mathematical methods to replicate them (Mandelbrot, 1982). “Statistical” fractals introduce randomness into their construction, such that only the pattern’s statistical qualities (e.g. density, roughness, complexity) repeat. Consequently, statistical fractals simply look similar at different size scales. Whereas exact fractals display the cleanliness of artificial shapes, statistical fractals capture the “organic” signature of natural objects (Figure 1).

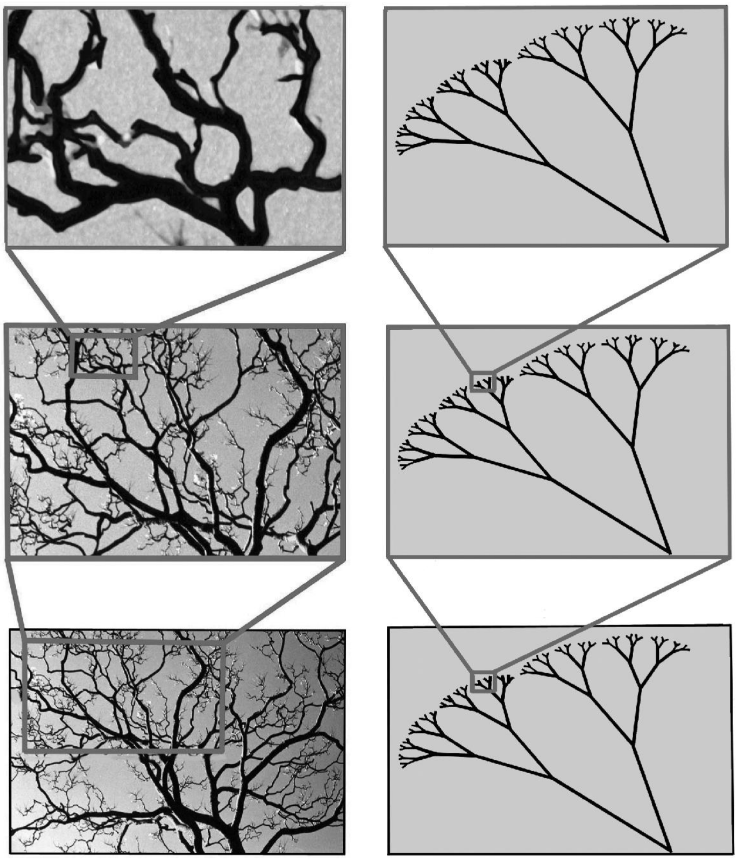

Figure 1. The branch patterns of an artificial tree repeat exactly at different magnifications (right column). In contrast, only the statistical qualities repeat for a real tree (left column). Images generated by RPT.

Statistical fractals are highly topical in the field of “bio-inspiration”, in which researchers investigate the favorable functionality of natural systems and apply their findings to artificial systems. The growing role of fractals in the arts suggests that the repeating patterns might serve a vital bio-inspired function by capturing the aesthetic quality of nature. Previous studies have shown that exposure to natural scenery can have dramatic, positive consequences for the observer (Ulrich, 1981; Ulrich, 1993; Ulrich & Simons, 1986). In particular, Roger Ulrich and colleagues showed that patients recover more rapidly from surgery in hospital rooms with windows overlooking nature. Although groundbreaking, these demonstrations of biophilic responses employed vague descriptions for nature's visual properties. Our research has built on these studies by testing a highly specific hypothesis—that the statistical fractals inherent in natural objects are inducing these remarkable effects (Taylor, Spehar, von Donkelaar, & Hagerhall, 2011; Taylor & Spehar, 2016).

As reflected in Figure 1, the repeating patterns of fractals generate highly complex images. However, some fractals are more complex than others depending on the amounts of coarse and fine patterns contributing to the fractal mixture. Because many of nature's fractals exhibit mid-range complexity, we proposed a "fractal fluency" model for the human visual system in which it has adapted to efficiently process these mid-complexity patterns (Taylor, Spehar, von Donkelaar, & Hagerhall, 2011; Taylor & Spehar, 2016). The model predicts that this "effortless looking" will result in the enhanced performance of visual tasks and, accordingly, the patterns will assume an aesthetic quality. The question of fractal aesthetics holds special significance for the field of experimental aesthetics. When one of its early pioneers, George Birkhoff, introduced "Aesthetic Measure" as a concept in the 1930s (the idea that aesthetics could be linked to measureable mathematical properties of the observed images) visual complexity was a central parameter in his proposals (Birkhoff, 1933).

Here, we first provide an historical review of the manifestation of fractals in art and architecture and then discuss two studies that highlight the positive consequences of incorporating them into the built environment. The first focuses on people's enhanced ability to navigate within mid-complexity fractal environments and the second highlights their aesthetic quality. Given that these positive impacts of fractals originate from their prevalence in nature, fractal architecture can be seen as a specific and highly practical example of "biophilia"—a term made popular by the conservationist E. O. Wilson to emphasize "the urge to affiliate with other forms of life" (Wilson, 1984).

BACKGROUND: FRACTALS IN ART AND ARCHITECTURE

Symbolic representations of fractals can be found in cultures across the continents spanning several centuries, including Roman, Egyptian, Aztec, Incan and Mayan civilizations. They frequently predate patterns named after the mathematicians who subsequently defined their visual characteristics. For example, although Helge von Koch is famous for developing *The Koch Curve* in 1904, a similar shape featuring repeating triangles was first used to depict waves in friezes by Hellenic artists (300 B.C.E.). In the 13th century, repetition of triangles in Cosmati Mosaics generated a shape later known in mathematics as *The Sierpinski Triangle* (named after Waclaw Sierpinski's 1915 pattern). Triangular repetitions are also found in the 12th century pulpit of *The Ravello Cathedral* in Italy. The lavish artwork within *The Book of Kells* (circa 800 C.E.) and the sculpted arabesques in *The Jain Dilwara Temple* in Mount Abu, India, (1031 C.E.) also both reveal stunning examples of exact fractals.

The artistic works of Leonardo da Vinci (da Vinci, 1998) and Katsushika Hokusai (Calza, 2004) serve as more recent examples from Europe and Asia, each reproducing the recurring patterns that they saw in nature. Da Vinci's sketch of turbulence in water, *The Deluge* (1571–1518), was composed of small swirls within larger swirls of water. In *The Great Wave off Kanagawa* (1830–1833), Hokusai portrayed a wave crashing on a shore with small waves on top of a large wave. His other woodcuts from the same period also feature repeating patterns at several size scales: *The*

Ghost of Kohada Koheiji shows fissures in a skull and *The Falls at Mt. Kurokami* features branching channels in a waterfall. From the 20th century, Jackson Pollock's abstract paintings have been shown to be just as fractal as nature's scenery (Taylor, 2002; Taylor, Micolich, & Jonas, 1999; 2002; Taylor et al., 2007). Although the fractal character of his poured patterns originated from the dynamics of his body motions (specifically an automatic process related to balance known to be fractal), he spent ten years consciously manipulating this process. His own reflections on the meaning of his patterns— "I am nature" and "my concerns are with the rhythms of nature"— suggest that he understood their link to nature. Other modern painters have also been shown to display fractal characteristics into their work (Forsythe, Williams, & Reilly, 2017; Graham & Field, 2008; Redies, Hasenstein, & Denzler, 2007).

An alternative strategy to relying on careful observation of nature's fractals is to employ mathematics to replicate them. The nautilus shell is one of the finest examples of a spiral found in nature, mathematics and art (Figure 2) (Taylor, 2012). Figure 2 shows an example by the artist Daniel Della-Bosca. Jacob Bernoulli was one of the first mathematicians to become fascinated by these spirals' properties: the size of the spiral decreases but its shape is unaltered with each successive curve, creating exact fractals. The spiral's rate of shrinking is set by the "Golden Ratio" (1.618), which is also called the "Divine Proportion" because of its proposed aesthetic qualities (Livio, 2002).

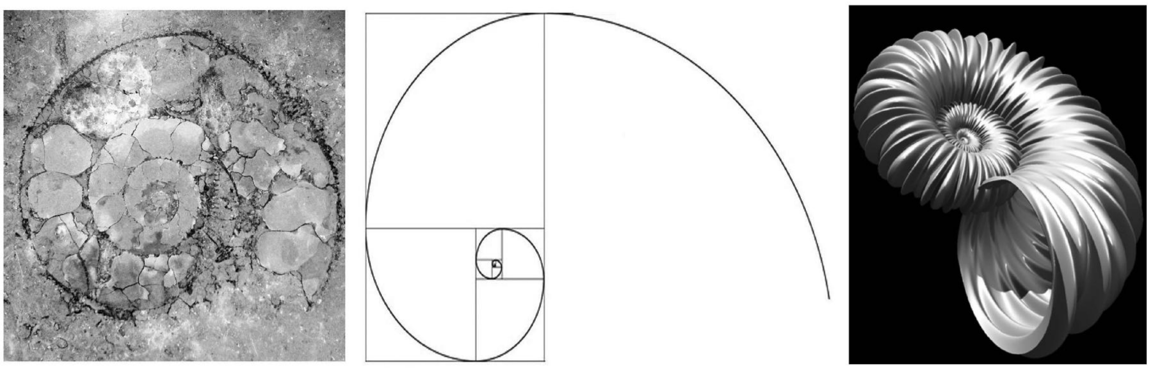

Figure 2. Left: A Nautilus fossil. Middle: A mathematical mapping of a Nautilus spiral. Right: Daniel Della-Bosca's Nautilus Sculpture.

The artist who integrated mathematics into art most effectively is Maurits Cornelis Escher. Inspired by the Islamic tiles that he saw during a trip to Spain's Alhambra, Escher took the bold step of incorporating patterns that repeat at many size scales into his art. "Since a long time I am interested in patterns with 'motives' getting smaller and smaller till they reach the limit of infinite smallness," he said (Escher, 1989). Escher's most famous prints, the *Circle Limit* series (1958–1960), reflect both the mathematical challenge and the troubled artistic road that he took to meet it (Figure 3) (Van Dusen & Taylor, 2013). Making his patterns fit together required considerable thought and a helping hand from mathematics. He finally found the solution in the mathematical work of Harold Coxeter who declared: "Escher got it absolutely right to the millimeter" (Coxeter, 1979).

Escher's patterns have captured the imaginations of both artists and mathematicians for more than half a century. Along the way, the patterns' connection with nature has fallen by the way side. His work is often presented as an elegant solution to a purely academic exercise of mathematics—a clever visual game. In reality, Escher's interest lay in the fundamental properties of natural patterns

(Taylor, 2009). He frequently sketched natural scenery, including the repeating patterns of tree branches and leaf veins. Escher declared: "We are not playing a game of imaginings—we are conscious of living in a material, three dimensional reality." He replicated nature in what he referred to as the "deep, deep infinity" of his repeating patterns. Intriguingly, Escher's *Circle Limit* series predated Mandelbrot's *Fractal Geometry of Nature* by 20 years.

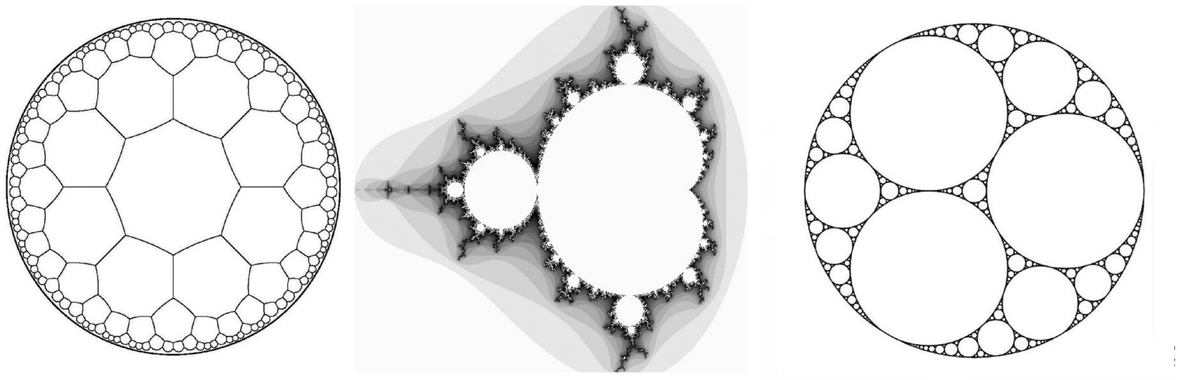

Figure 3. Examples of fractals: The repeating structure used in Escher's Circle Limit series (left), the Mandelbrot Set (middle), and an Apollonian Foam (right). Images generated by RPT.

Soon after Mandelbrot declared fractals to be nature's geometry, he and other mathematicians developed the most published image generated by any mathematician—*The Mandelbrot Set* (Figure 3). Part of its intrigue is that it contains exact fractals in the regions called the Misiurewicz Points and statistical fractals elsewhere. The underlying rules used to construct the image were astonishingly simple but nevertheless required computers to generate the complexity of layer upon layer of fractal patterns. Although similar equations had appeared earlier in the 20th century (such as those of the equally famous Julia Set, named after the mathematician Gaston Julia), it was not until the 1980s that Mandelbrot had the necessary computing power to generate the pictures from the equations. Just as microscopes and telescopes transformed biology and astronomy, the modern microprocessor radically expanded people's ability to explore and create fractal patterns. Today, there are many examples of computer art that use fractals—either exact or statistical—as the building blocks of their patterns. Computer technology continues to push fractal arts' creative boundaries. The Mandelbulb is a 3-dimensional analog of the Mandelbrot Set, first constructed in virtual space by Daniel White and Paul Nylander in 2009. Author and mathematician Rudy Rucker had proposed Mandelbulbs 20 years earlier, but he lacked the contemporary computing power to display them.

Although computers can fill virtual worlds with the rich patterning of fractals, in the physical world they are almost exclusively the trademark of nature. However, 3-dimensional printers now allow intricate patterns designed by computers to be printed ("contour-crafted") as physical objects. Della-Bosca used "3-*D*" printers to construct the fractal sculpture shown in Figure 2. Much like a walk through nature's forests, his sculptures surround you, invite you on a journey that is both visual and tactile. This physicality serves as the driving force behind the creation of his sculptures. He sees his 3-dimensional sculptures as an obvious approach to capturing nature's fundamental appeal. Mandelbrot has previously noted: "In order to understand geometric shapes, I believe that you have to see them" (Della-Bosca & Taylor, 2009). Della-Bosca has taken this thought one step further by asking "What happens if you touch them, too?" The leap from fractal sculpture to fractal architecture seems equally logical to Della-Bosca: "We require our environment to keep us physically, mentally, and emotionally fulfilled, so it is logical to assume that the built environment should not be filled with empty geometry but should be as rich and detailed as we can make it" (Della-Bosca & Taylor, 2009).

Advocates of fractal architecture (Bovill, 1995; Joye, 2007; Salingaros, 1999; Salingaros, 2002; Salingaros, 2006; Salingaros & West, 1999) are often inspired by the work of the architect Christopher Alexander who was a critic of conventional architecture and its lack of reflection of human aspirations and needs (Alexander, 1975). Yet, although fractals appear in the patterns generated by the skylines (Stamps, 2002) and boundaries (Batty & Longley, 1994) of cities, fractal buildings remain conspicuously absent. So why are not today's urban landscapes dominated by fractal buildings? The answer is as simple as it is daunting—with each layer of repeating pattern, the escalating costs send builders running back to the rectangular box. However, although fractal repetition has been considered too extravagant for buildings, there have been many cases of architecture attempting to symbolize it by incorporating a few repeating layers. The Borobodur temple built in Java during the 8th century (Figure 4) is an early example (Taylor, 2006). The Castel del Monte, designed and built by the Holy Roman Emperor Frederick II, has a basic shape of a regular octagon fortified by eight smaller octagonal towers at each corner. Gothic cathedrals of Europe (12^{th} century) also exploit fractal repetition in order to deliver maximum strength with minimum mass. The fractal character also dominates the visual aesthetics of these buildings. A Gothic cathedral's repetition of different shapes (arches, windows, and spires) on different scales yields an appealing combination of complexity and order (Goldberger, 1996).

The Ryoanji Rock Garden in Japan represents an example from the 15^{th} century (Van Tonder, Lyons, & Ejima., 2002). Gustav Eiffel's tower in Paris (1889) is a more recent demonstration (Figure 4), highlighting the practical implications of fractal architecture. If the tower had been designed as a solid pyramid, it would have required a large amount of iron without significant added strength. Instead, Eiffel exploited the structural rigidity of a triangle at many different size scales. Frank Lloyd Wright's repetition of a triangle adds to the visual appeal of his Palmer House in Ann Arbour (USA, 1950–1951) (Eaton, 1998). The organic quality of Frank Gehry's contemporary architecture has also been discussed in terms of fractals (Taylor, 2001). Going beyond the design of individual buildings, complexes within African villages have been shown to follow a fractal plan (Eglash, 2002).

More recently, explorations of bubble patterns led to a famous example of modern architecture (Taylor, 2011). Foams form intricate patterns that efficiently pack a range of bubble sizes into a small area. The Apollonian pattern (Figure 3) is an example of a fractal foam in which increasingly small bubbles are packed into the gaps that inevitably form between the larger bubbles. In 1993, Denis Weaire used computer simulations to determine the optimal packing pattern for foam (Weaire, 1997). The resulting structure served as the inspiration for the aquatic center at the Olympics in Beijing in 2008. The foam pattern of the so-called *Water Cube* is shaped by more than 22,000 steel beams. Shapes of varying size cram together into a pattern that appears to be disordered—but only superficially. The underlying structure follows the geometric order required by nature's rules of foam formation.

The above review highlights the prevalence of fractals in art and architecture throughout history. In the future, 3-dimensional printers will be able to move beyond these symbolic demonstrations in which a limited number of repetitions were employed. This revolutionary technology will print whole rooms, allowing assembly into buildings, making fractal architecture a practical proposition.

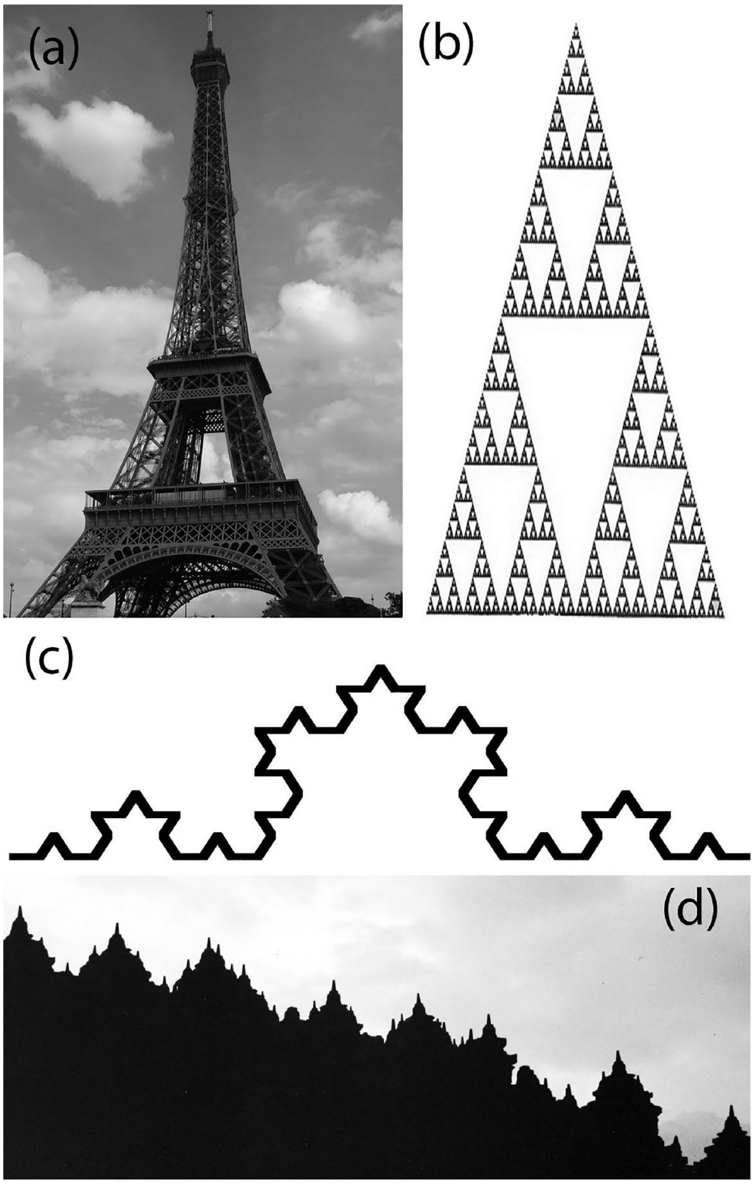

Figure 4. The Eiffel Tower (a) compared to a Sierpinski Triangle (b) and a Kock Curve (c) compared to the Borobodur Temple. Images generated/photographed by RPT.

With this in mind, in the next section we will review some of the advantages of adopting these fractal designs.

FRACTAL FLUENCY

To quantify the visual complexity of the fractal images used in our studies, we adopt a traditional mathematical parameter called the fractal dimension D, which describes how the patterns occurring at different magnifications combine to build the resulting fractal shape (Fairbanks & Taylor, 2011; Mandelbrot, 1982). For a smooth line (containing no fractal structure) D has a value of 1, while for a completely filled area (again containing no fractal structure) its value is 2. However, the repeating patterns of the fractal line cause the line to begin to occupy space. As a consequence, its D value lies between 1 and 2. By increasing the amount of fine structure in the fractal mix of repeating patterns, the line spreads even further across the two-dimensional plane and its *D* value therefore moves closer to 2.

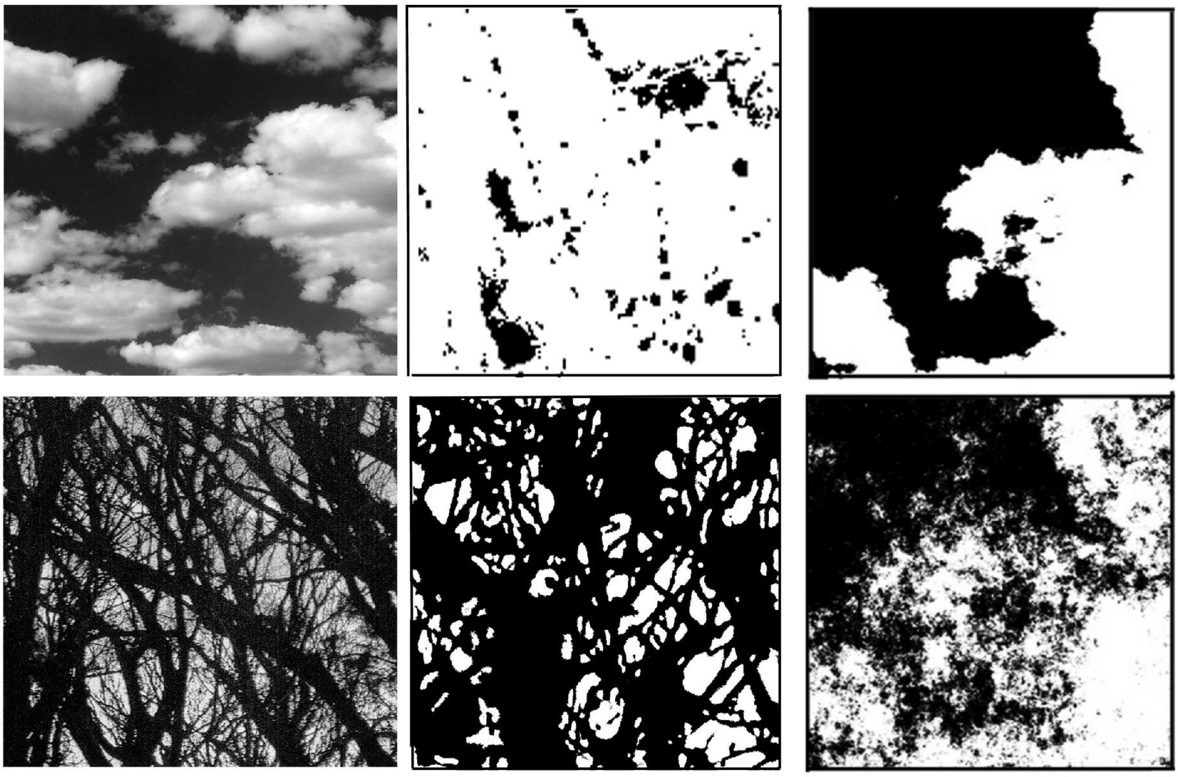

Figure 5. Fractal complexity in nature, art and mathematics. The left column shows clouds with *D* = 1.3 (top) and a forest with *D* = 1.9 (bottom). The middle column shows Jackson Pollock's *Untitled* 1945 with *D* = 1.1 (top) and Untitled 1950 with *D* = 1.89 (bottom). The right column shows computer-generated fractals with *D* = 1.2 (top) and *D* = 1.8 (bottom).

Figure 5 demonstrates how a statistical fractal's *D* value has a crucial effect on the visual characteristics of fractal patterns found in nature (photographs of clouds and trees), art (paintings generated by Jackson Pollock) and mathematics (computer-generated images) (Spehar, Clifford, Newell, & Taylor, 2003). For fractals described by low *D* values (i.e. closer to 1), the relatively small content of fine structure builds a very smooth sparse image. However, for fractals with *D* values closer to 2, the larger amount of fine structure builds an image full of intricate structure. More specifically, because the *D* value charts the ratio of coarse to fine structure, it is expected that *D* will serve as a useful measure of the visual complexity generated by the repeating patterns. Behavioral research by our group (Spehar, Walker, & Taylor, 2016) and others (Cutting & Garvin, 1987) confirms that the complexity perceived by observers does indeed increase with the image's *D* value (Figure 6).

The physical processes that build nature's fractals determine their *D* values. Although objects appearing in natural scenes are described by *D* values across the range $1.1 < D < 1.9$, the most prevalent fractals lie between 1.3 - 1.5. We therefore proposed a fluency model in which the human visual system has adapted to efficiently process the mid-complexity patterns of these prevalent *D* = 1.3 - 1.5 fractals (Taylor, Spehar, von Donkelaar, & Hagerhall, 2011; Taylor &

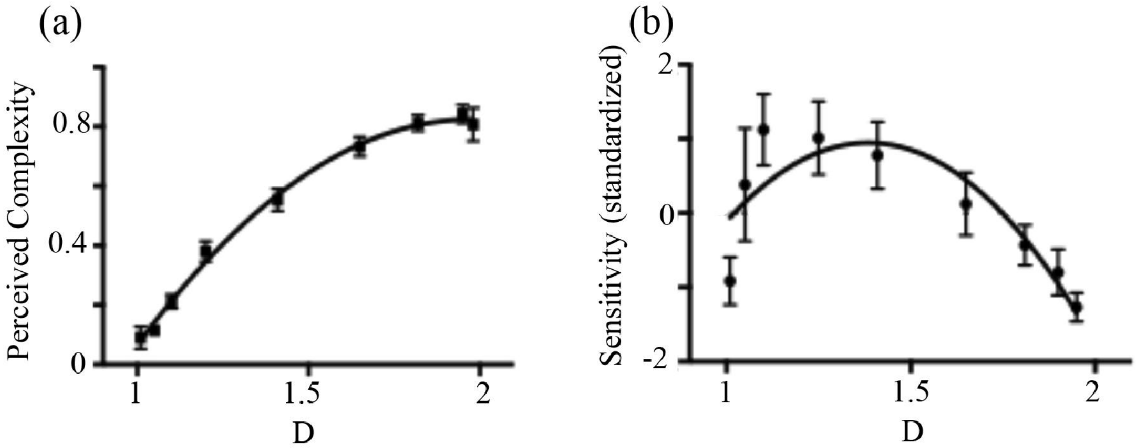

Figure 6. (a) Using fractal images similar to the computer-generated images shown in Figure 5, an investigation of 310 participants revealed that perceived complexity increases with the fractal's *D* value. (b) An investigation involving 68 participants revealed a peak discrimination sensitivity for fractals with mid-*D* values.

Spehar, 2016). This model predicts that the increased processing capabilities should result in enhanced performances of visual tasks when viewing mid-*D* fractals. This model was confirmed using computer-generated fractal images that repeat over a magnification range of 100 (similar to typical natural fractals). Using these images, our behavioral studies demonstrated participants' heightened sensitivity to mid-*D* fractals (Spehar, Wong, van de Klundert, Lui, Clifford, & Taylor, 2015). As shown in Figure 6, participants displayed a superior ability to distinguish between fractals with different *D* values in the mid-*D* range (Spehar, Wong, van de Klundert, Lui, Clifford, & Taylor, 2015). Similarly, participants exhibited a peak in detection sensitivity for mid-*D* fractals. To demonstrate this, fractal patterns were displayed on a monitor and the contrast between the dark pattern and its light background was gradually reduced until the monitor displayed uniform mean luminance. We found that the participants were able to detect the mid-*D* fractals for much lower contrast conditions than the low and high *D* fractals (Spehar, Wong, van de Klundert, Lui, Clifford, & Taylor, 2015).

A further demonstration of increased processing capabilities was identified by measuring participants' EEG responses to viewing fractals, which highlighted the ability to maintain attention when observing mid-*D* fractals (Hagerhall, Laike, Taylor, Küller, Küller, & Martin, 2008; Hagerhall, Laike, Küller, Marcheschi, Boydston, & Taylor, 2015). There is also evidence to suggest that pattern recognition capabilities increase for mid-*D* fractals. We are all familiar with percepts induced by clouds (Figure 7). A possible explanation is that our pattern recognition processes are so enhanced by these fractal clouds that the visual system becomes "trigger happy" and consequently we see patterns that are not actually there. Research reveals that mid *D* fractal images activate the object perception and recognition areas of the visual cortex (Bies, Wekselblatt, Boydston, Taylor, & Sereno, 2015) and allow for a larger number of percepts to be formed (Bies, Kikumoto, Boydston, Greenfield, Chauvin, Taylor, & Sereno, 2016). This is consistent with behavioral studies in which the capacity to perceive shapes in fractal images was shown to peak in the low *D* range (Rogowitz & Voss, 1990; Taylor et al., 2017).

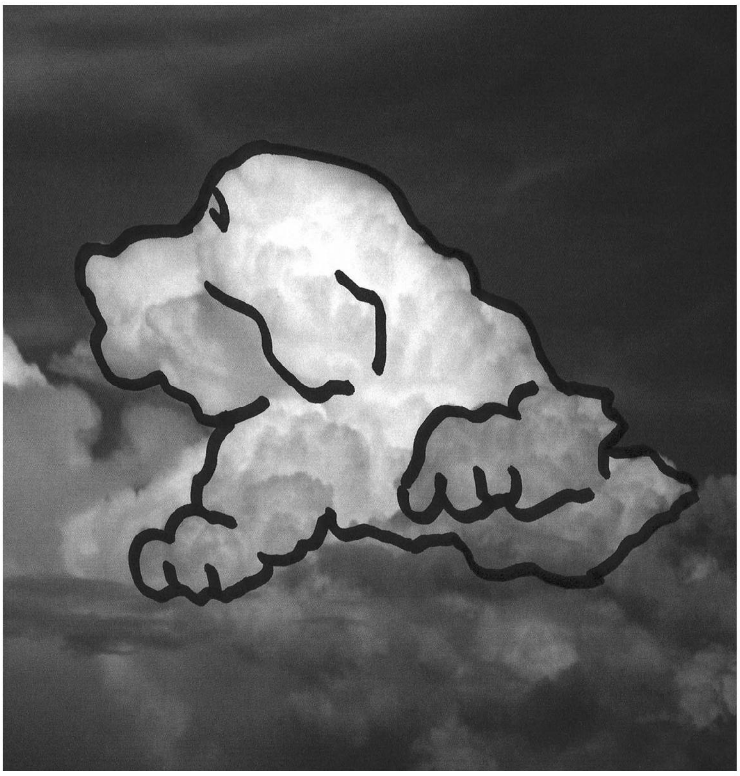

Figure 7. A photograph of clouds with the perceived image of a dog drawn on it. Photograph by RPT.

Does fractal fluency also lead to an enhanced processing of visual spatial information and therefore to a superior ability to navigate through environments characterized by mid-*D* fractals? To answer this important question for fractal architecture, we generated virtual fractal environments characterized by varying *D* values (Juliani, Bies, Boydston, Taylor, & Sereno, 2016). Virtual environments have been used in navigational research for several decades (Loomis, Blascovich, & Beall., 1999; Nash, Edwards, Thompson, & Barfield, 2000) and have been shown to be good approximations of physical environments for transferring navigational skills to their real-world equivalents (Arthur & Hancock, 2001; Richardson, Montello, & Hegarty, 1999). Human performance in complex virtual environments has often been studied using regular geometric structures such as mazes (Chrastil & Warren, 2013; Moffat, Hampson, & Hatzipantelis, 1998; Wolbers & Büchel, 2005). However, such studies do not capture the fractal complexity inherent in natural environments. Other research has replicated the features of specific natural environments (Darken & Banker, 1998; Witmer, Bailey, & Knerr, 2000; Stürzl, Grixa, Mair, Narendra, & Zeil 2015) which required time-consuming physical collection of environmental information and was expensive to carry out. In contrast, our approach generates controlled environments in which the generic fractal qualities can be tuned with precision and ease.

Generation of the virtual landscapes is described in detail elsewhere (Juliani, Bies, Boydston, Taylor, & Sereno, 2016). They each spanned 200m in virtual space and consisted of flat ground with protruding fractal hills of maximum height 50m. Figure 8 demonstrates the impact of varying *D*. Seventy-four participants navigated an avatar through the landscapes from a first-person perspective using a PlayStation controller and they could move their avatar not only around the flat surface but also over terrains with inclines of less than 45^0. They were instructed to search as quickly as possible for the goal (e.g. a coconut) randomly placed within the landscape. Various experimental conditions were investigated, including the effect of including a topographic map featuring the goal's location, the presence of a distractor goal (e.g. a second coconut), and making the goal invisible (e.g. by burying it). Including these conditions allowed for confirmation that the experimental conditions indeed measured navigational performance above and beyond the difficulties of simply moving around the features of the environments (Juliani, Bies, Boydston, Taylor, & Sereno, 2016). In each case, completion speeds and accuracy (the ratio of finding the goal before or after arriving at the distractor) were measured.

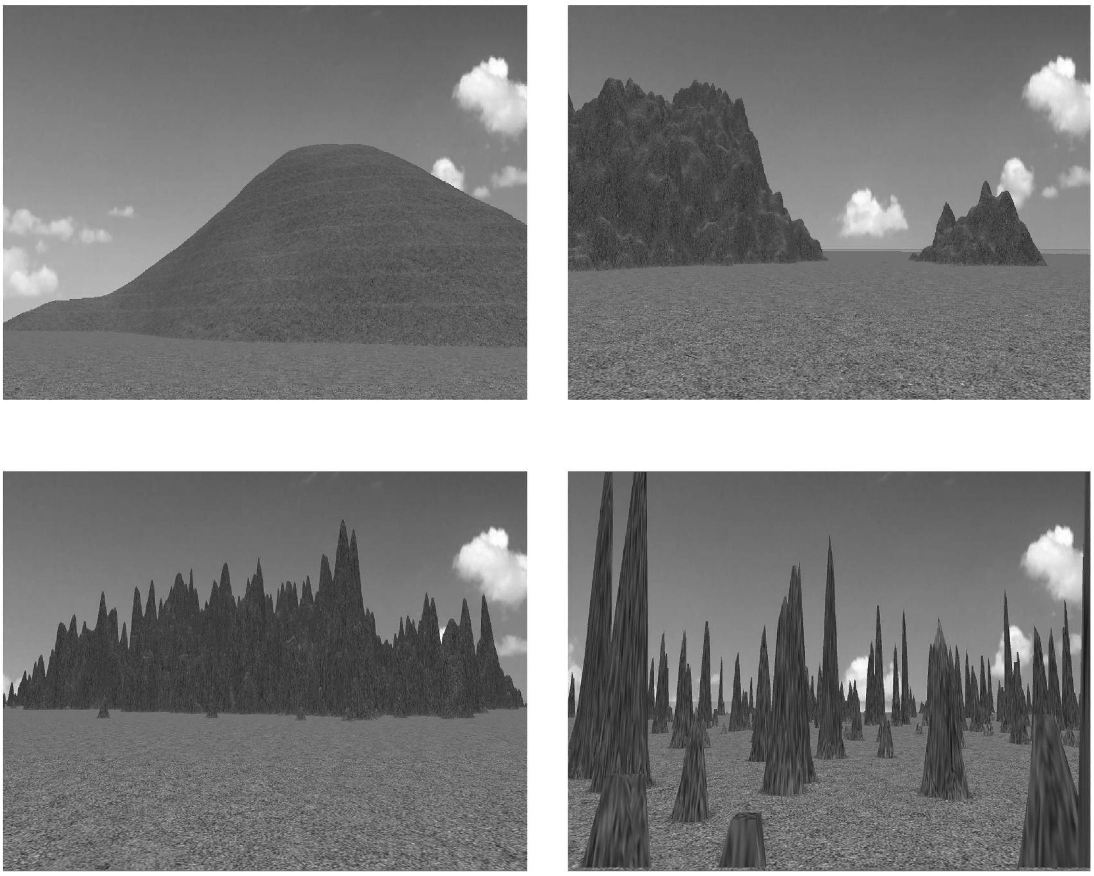

Figure 8. Examples of first-person perspective views during the navigation experiment. The D of the landscapes are 1.1 (top-left), 1.3 (top-right), 1.7 (bottom-left) and 1.9 (bottom-right).

Figure 9 shows an example result for the condition in which the goal was buried and the participants read a map to guide them to the goal. The measure of accuracy was designed to convey the ability of participants to make precise localization judgments on a scale that ranged from 0 (designating chance performance) to 100 (designating perfect performance) (Juliani, Bies, Boydston, Taylor, & Sereno, 2016). In order to account for both accuracy as well as time-to-goal within a single construct, we also calculated a measure of overall performance and found that this too peaked at mid-*D* complexity. This navigation performance closely matches that expected from the fluency model.

In addition to effective navigation through a fractal environment, fractal fluency creates a unique aesthetic quality due to the relative ease with which fractals can be processed. In 1993, we conducted the first aesthetics experiments on fractals, showing that 95% of observers preferred complex fractal images over simple Euclidean ones (Taylor, 1998). Soon after, others employed computer-generated fractals to show that mid-*D* fractals were preferred over low and high *D* fractals (Aks & Sprott, 1996). Over the past two decades, fractal aesthetics experiments performed by ourselves and others have shown that preference for mid-*D* fractals is universal rather than dependent on specific details of how the fractals are generated. We showed that preference for mid-*D* patterns occurred for fractals generated by mathematics, art and nature using images similar to those shown in Figure 5 (Spehar, Clifford, Newell, & Taylor, 2003). Whereas this experiment featured relatively simple natural images such as a tree or a cloud, this was soon broadened to include more complex natural scenes featuring many fractals (Hagerhall, Purcell, & Taylor, 2004) and also larger varieties of computer-generated fractals (Spehar and Taylor, 2013; Spehar, Walker, & Taylor, 2016).

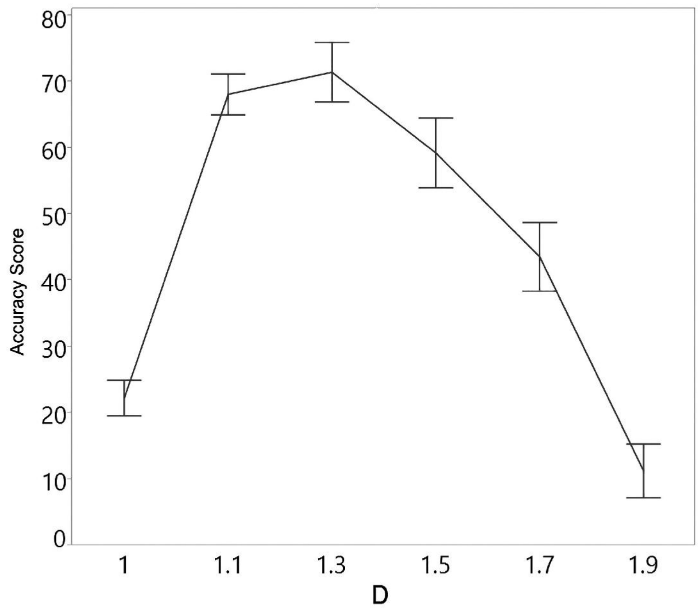

Figure 9. The relationship between *D* and the mean accuracy (see main text), revealing a peak in navigation performance at *D* = 1.3.

Figure 10 shows preference results for 20 participants who viewed computer-generated stimuli similar to those shown in Figure 5 (Taylor, Spehar, von Donkelaar, & Hagerhall, 2011). The panels are for four different "configurations" in which the computer used four different seed patterns to build the fractal images. The peak preference showed a remarkable consistency despite superficial variations in the four fractal seeds. Furthermore, this peak behavior for aesthetics follows that revealed in Figure 6 for the observer's processing abilities (as quantified by their abilities to detect and discriminate fractals). In addition to these laboratory-based behavioral experiments, others have used a computer server to send screen-savers to a large audience of 5000 people. New fractals were generated by an interactive process between the server and the audience, in which users voted electronically for the images they preferred (Taylor & Sprott, 2008). In this way, the parameters generating the fractal screen-savers evolved with time, much like a genome, to create the most aesthetically preferred fractals. The results re-enforced the preference for mid-*D* fractals found in the laboratory-based experiments. This "aesthetic resonance" for *D* = 1.3 - 1.5 fractals also induces the state of relaxation indicated by the peak in alpha response in the qEEG studies and by skin conductance measurements (Hagerhall, Laike, Taylor, Küller, Küller, & Martin, 2008; Taylor, 2006). Whereas the above experiments focused on the universal responses to fractals, more recent experiments have started to examine the subtle differences in responses between individuals (Bies, Blanc-Goldhammer, Boydston, Taylor, & Sereno, 2016; Spehar, Walker, & Taylor, 2016; Street, Forsythe, Reilly, Taylor, Boydston, & Helmy, 2016) and also different forms of fractals (for example, exact versus statistical fractals) (Bies, Blanc-Goldhammer, Boydston, Taylor, & Sereno, 2016).

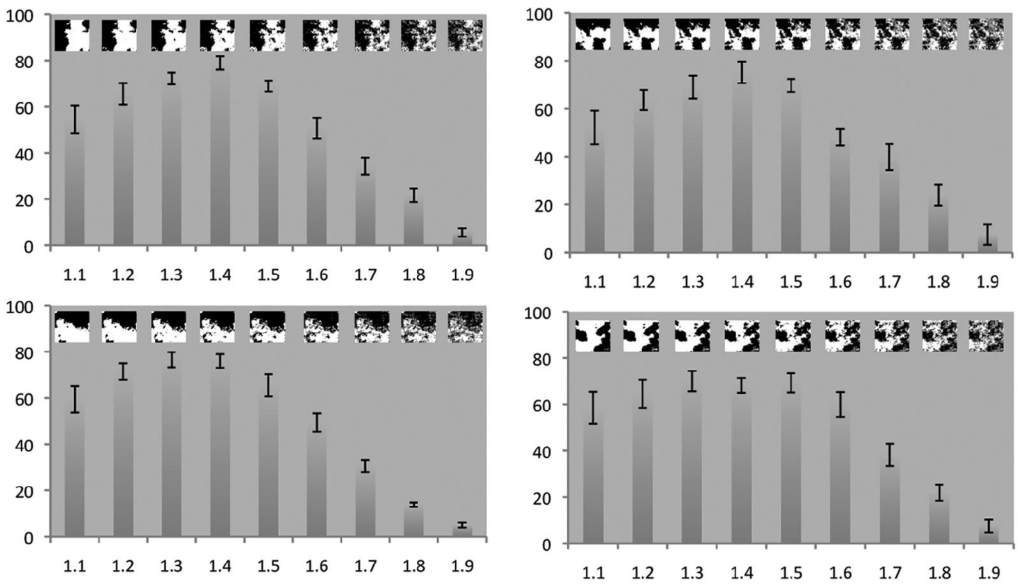

Figure 10. Visual preference for computer-generated fractal patterns. For each of the four panels, *D* is plotted along the x-axis and the preference on a scale 0–100 is plotted along the y-axis. Each of the four panels uses a different fractal configuration to investigate preference. The fractal images are shown as insets in each panel.

CONCLUSION

Our historical review of fractals highlights a natural inclination on the part of artists and architects to design buildings and environments which capture the visual essence of fractal geometry. With the advent of 3-*D* printing techniques, we expect that this inclination will be more frequently transformed from imagination into practicality. Accordingly, we have reviewed our recent psychology experiments on fractal fluency to demonstrate that people will display enhanced visual capabilities in fractal environments characterized by mid-complexity. In particular, people will be able to navigate effectively through these spaces and will benefit from their aesthetic and stress-reducing effects. Given that job stress alone is estimated to cost American businesses many millions of dollars annually (Smith, 2012) the latter effect holds a huge potential benefit to society.

Finally, we note that there are other "bio-inspiration" motivations for creating a building based on fractals. Fractals have large surface area to volume ratios. For example, trees are built from statistical fractals in order to maximize exposure to the sunlight. Similarly, bronchial trees in our lungs maximize oxygen absorption into the blood vessels. Possible advantages of this large surface area for fractal buildings include solar panels on the rooftops and windows that deliver a large amount of light to the building's interior. The repeating structures of fractals also dissipate the energy of impinging waves. For example, the energy of ocean waves crashing on the shoreline is dissipated by the fractal coastlines and this reduces erosion. For this reason, modern storm barriers feature fractal surfaces. Similarly, trees serve as effective windbreakers compared to flat surfaces because their fractal branches dissipate the wind's energy. Mathematicians have even shown that if the circular shape of a drum is replaced by a fractal, it will dissipate vibrations so effectively that it will not make a noise when struck by the drum stick (Peterson, 1994)! As a consequence, fractal building designs will minimize noise and vibrations from traffic and earthquakes. When all of these physical advantages are coupled with the visual impacts covered in this article, it becomes clear that artificial fractal environments have a bright future.

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Human-Nature Interaction Patterns: Constituents of a Nature Language for Environmental Sustainability

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ABSTRACT

Many environmentalists are focused on "saving" nature, but if people do not interact with nature, these efforts will not be enough. Thus, this article focuses on characterizing human-nature interaction based on the idea of *interaction patterns*: characterizations specified concretely so as to establish a meaningful category while abstractly to allow for endlessly unique instantiations. Over 60 interaction patterns are discussed to illustrate the idea of interaction patterns, *keystone* interaction patterns, and a Nature Language. Finally, we propose a new design approach, *Interaction Pattern Design*, and show how it extends biophilic design, and can be used to deepen a vision and the practice of environmental sustainability: from that of surviving to thriving through experiencing the fullness of life.

Keywords: human-nature interaction; interaction pattern design; biophilic design; human flourishing; nature language

INTRODUCTION

Sustainability is a term that is moving a lot of environmental discourse and activity in the world today. Yet, to our minds, it is often an extraordinarily underwhelming term. African elephants in a zoo can often live long lives in confines no bigger than a parking lot; and in that sense they are sustainable in the zoo environment. But how are they doing? As Bradshaw (2013) shows, not so well: tormented, neurotic, distorted shells of their former selves. It could be said we are becoming like those elephants, caged in our own urban confines. We adapt, yes. But even as we adapt, we suffer physically and psychologically, and then establish new baselines for what we consider "normal" living (Hartig & Kahn, 2016; Kahn, 2002, 2007, 2011; Pyle, 2002). So, as the world talks about sustainability, we could be asking for very little if we are not holding out a vision of the fullness of life that we want to sustain.

The fullness of life includes rich, daily contact with a diverse and abundant natural world. Why? For one reason, as a species we came of age with this nature, and the need for it lies deep still within the architecture of our bodies, minds, and spirits (Kellert, 1997; Kellert & Wilson, 1993; Wilson, 1984). We are optimally embodied to thrive within nature, including wild nature, even as we adapt to our increasingly urban and technological world (Kahn, 2011, Kahn & Hasbach, 2013; Shepard, 1998). Interaction with nature is a precondition for our physical and psychological wellbeing (Frumkin, 2012). But as we lose the interaction, it sets into motion a terrible cycle—which the modern world is now in—where we care less about nature and destroy it more; and as we destroy it more there is less nature to interact with, which leads to caring even less and its further destruction.

How then can we break this cycle? As an analogous question, how do we teach children to swim? We could teach them about the physiology of swimming, lecture them about its history, teach about the chemical composition of water, and show video clips of Olympic medalists in their winning races. Will the children know how to swim? No. Will they love swimming? No. Will they want to protect natural swimming holes? Unlikely. It is obvious what is missing. To teach children to swim, we need to get them into the water. The interaction with water is primary. Everything else is secondary.

Thus in this article we put forward an approach that can contribute to environmental sustainability that is based on human-nature *interaction patterns*. We begin by explaining what interaction patterns are, and how they become constituent parts of what we call a *Nature Language* (Kahn, Ruckert, & Hasbach, 2012; Kahn, Ruckert, Severson, Reichert, & Fowler, 2010). Next, we provide examples of four higher order interaction patterns—keystone interaction patterns—and many complementary interaction patterns that help constitute them, so as to begin to convey the power of this way of characterizing human-nature interaction**.** Finally, we propose a new design approach, *Interaction Pattern Design,* and discuss how it extends biophilic design, and can be used to deepen a vision and the practice of environmental sustainability.

INTERACTION PATTERNS

Interaction patterns are characterizations of essential features of interaction between humans and nature, specified abstractly enough such that countless different embodied versions of the interaction—what we will refer to as *instantiations* of the interaction—can be uniquely realized given different types of nature, people, and purposes.

The idea of human-nature interaction patterns builds from the pioneering work of Christopher Alexander in architecture wherein he and his colleagues developed a "pattern language" for the built environment. They generated 256 architectural patterns (Alexander, 1979; Alexander, Ishikawa, & Silverstein, 1977), ranging from the design of furniture, to city cafes, to the optimal proportion of pavement within an urban infrastructure. In their use of the term pattern, they meant not a cookie-cutter pattern (with each cookie being identical to the rest) but a generalized configuration that can be instantiated in endlessly different ways, depending on the specifics of one's built environment. For example, of their patterns they name: *Windows on Two Sides of a Room*. They say that when people have the choice, they will always gravitate to such rooms because such rooms are more conducive to human conviviality and wellbeing than if windows are on only one side of a room (or a windowless room). The pattern does not say what type of windows, or how large, or how they should be situated. That is for the designer to figure out. But the pattern provides a principle to build with.

This emphasis on a generalized configuration without in a sense "hardcoding" a specific instantiation—but allowing for endless configurations—is the idea behind a human-nature interaction pattern. For example, consider historically a Native American *Fishing the Waters* by standing on a large boulder above a river and spearing a salmon, compared with a present-day North American wearing waders and fly-fishing for trout in a mountain lake. The interaction pattern *Fishing the Waters* is recognizable in each, though enacted differently across culture and time. Of course, *Fishing the Waters* is not the only interaction happening in such situations. The Native American might be *Climbing a Boulder*, *Balancing on a Boulder over Big River*, *Feeling Sun on One's Back*, *Reading the Signs of a River, Spotting a Salmon, Spearing a Salmon,* and *Killing a Salmon*. The modern day trout fisherman might be *Wading into a Lake, Balancing in Lake*, *Reading the Signs of Trout, Presenting Fly to Trout, Hooking a Trout, Landing a Trout, Holding a Hooked Trout in Water, Releasing a Trout.* The interaction patterns can be said to become constituents of each person's "story" of the event, part of their *Nature Language.*

A NATURE LANGUAGE

By a Nature Language we mean a way of speaking about patterns of interactions between humans and nature, and their wide range of instantiations, and the meaningful, deep, and often joyful feelings that they engender.

Why is a Nature Language important? One way to answer is to draw on anthropologists and others who have shown that language makes possible ways of being, sensing, and living. Prechtel (1998), for example, lived with a Tzutujil Mayan village on the shores of Guatemala's Lake Atitlán. He notes that the "Tzutujil language has no word or phrase to say, 'I am leaving home.' Linguistically, you could only leave a place that wasn't home, to come home… It was built into the language that as soon as you took one step out of the village, you were already on the journey home, which of course was complete when you returned, but the 'going' was part of the returning. No matter what, we were always pointed toward part of the returning" (p. 104). This example shows a deep sense in which language embodies a people's belongingness to place.

But as we lose the embodiment of our actions we lose the language that speaks of them. The daily loss of one furthers the daily loss of the other. This is why Davis says that the loss of language is a sign of a vanishing culture:

> Language isn't just a body of vocabulary or a set of grammatical rules; it's a flash of the human spirit, the vehicle through which the soul of each particular culture comes into the material world. When you and I were born there were 6,000 languages spoken on Earth. Now, fully half are not being taught to schoolchildren. Effectively, they're already dead unless something changes. What this means is that we are living through a period of time in which, within a single generation or two, by definition half of humanity's cultural legacy is being lost in a single generation (Davis, 2002)

Prechtel also writes that the "The Tzutujil didn't hide their culture in scrolls, caves, or museums. They kept it alive by hiding it in a living language" (p. 118). A culture will not survive long without its language.

We are suggesting that we are losing the language of rich, deep, meaningful, nuanced, daily interactions with an abundant nature as we are losing that nature to interact with. Nature will not survive unless we can speak it; and we cannot speak it unless we live it. That is the reason we focus on interaction with nature, and of those embodied interactions becoming constituent elements of a Nature Language.

WILD, DOMESTIC, AND PERVERSE INTERACTION PATTERNS

Most interaction patterns can be instantiated—by which we mean, again, that they can take a specific embodied form—in more wild or more domestic ways. *Fishing on Top of a Boulder over a Big Unmanaged River with Spear in Hand* is more wild than *Spin-casting into a Stocked Trout Pond*. *Running a Mountain Trail* is more wild than *Running around a Quarter-mile Track*. *Watching a Sunset while Camped High on a Ridge* is more wild than *Watching a Sunset from the Safety of one's Deck*. *Soaking one's Feet in a Forested River* is more wild than *Soaking one's Feet in a Swimming Pool* (Figure 1).

Figure 1. Interaction Pattern: *Soaking Feet in Water*.
The photograph on the left represents a more wild instantiation of the interaction pattern than the photograph on the right (Photographs by Peter Kahn and Markus Spiske).

If we cannot experience interaction patterns in wild or domestic forms, then they often become instantiated in perverse ways. An example of this is the interaction pattern *Recognizing and Being Recognized by a Non-Human Other*. A *wild* instantiation of this interaction pattern is the experience of meeting eye-to-eye with a bear in the mountains. There is a moment of exhilaration and awe as you look into the bear's eyes and see and recognize bear consciousness. You are not sure what will happen next. Perhaps the most amazing thing is that you see the bear looking into your eyes, and understand that the bear is recognizing you from his consciousness. A less wild instantiation of this interaction pattern is looking in the eyes of fawn, and the fawn looks into your eyes. A more *domestic* instantiation of this interaction pattern is being greeted by the family dog upon your return home from work. There is a mutual recognition of one another as eyes meet. A *perverse* instantiation of this interaction pattern some of you have likely witnessed at a zoo. People can be seen throwing small pebbles or pieces of food at an animal in a cage, or banging on the glass of its enclosure, despite signage asking them not to do so. Most people are not interested in harming the wild animals, but want to get their attention. They want to be seen, recognized, by the Other. It is a perversion because they are asking wild animals in captivity against their will to recognize their captors. With interaction patterns, we could create a little motto: Enact them healthy, or suffer them sick.

KEYSTONE INTERACTION PATTERNS

For many purposes—such as in the design process—it can be useful to recognize interaction patterns that play a disproportionate role in human-nature interaction because the specific interaction (a) is itself hugely beneficial or meaningful, (b) engenders dozens or even hundreds of complementary, subsidiary, or overlapping interaction patterns, and/or (c) if lost leads to the subsequent loss of dozens or even hundreds of complementary, subsidiary, or overlapping interaction patterns. We refer to these as *keystone interaction patterns*. This term partly mimics the term *keystone species* in conservation biology, which refers to a species (such as a top predator) that has a disproportionate benefit to its environment relative to its abundance (Mills, Soulé, & Doak, 1993; Paine, 1995). For example, if the wolf (a keystone species) is removed from such areas as Yellowstone National Park, then elk grow more abundant and stationary, overgrazing vegetation, which leads to the loss of habit, increased erosion, and the loss of biodiversity (Eisenberg, 2013). Similarly, when air is so massively polluted (as it sometimes is in, say, Beijing and Shanghai) that it prevents people from *Walking Outside*, then the loss of that interaction leads to the loss of every human-nature interaction that requires being outside. In this way, *Walking Outside* is a keystone interaction pattern, perhaps the broadest and most fundamental insofar as "outside" encompasses all of nature that exists beyond human-made enclosed physical space.

Most keystone interaction patterns specify more specific domains of nature. For illustrative purposes, we discuss three keystone interaction patterns.

1. Walking to a Desired Destination in Nature

It is one of the oldest interaction patterns that exists within our species. We have walked to desired locations in nature ever since we have had legs. Some exercise physiologists say that if you are looking for the best exercise, it is walking (Reynolds, 2011). In terms of sustainable urban design, European cities have traditionally been comprised of *walkable* neighborhoods. Small food markets, shopping stalls, cleaners, restaurants, taverns, and cafés within walking distance of one's residence. You walk to get to a desired location in the course of a day. You do not need to get on a treadmill for two miles with your earbuds in place embedding digital sound to keep you from being bored. No, you walk to get to a place you want to go. In the process you see things of interest, meet neighbors, *Encounter the Weather*, *Feel the Wind*, *Hear Bird Song* and then arrive with the satisfaction of having arrived. You have "exercised" without having to call it that.

The same holds true while walking to a destination in nature. You can *Walk to Central Park* in New York City, and then within the park *Walk to One of the Lakes*. Or in a city or rural area you can *Walk to the Top of a Ridge Line*, and in other areas *Hike to the Top of a Mountain*. We are drawn to promontories, perhaps because from ancestral times they provided greater safety due to their geographical relief (Heerwagen & Orians, 1993). On your hike, you might *Find Special Spots in Nature* that allow you to *Gaze onto Large Expanses of Terrain* as you *Watch Clouds Form*; or to *Find and Sit on a Fallen Stump* that perfectly fits your body and provides you rest, or to *Sit Under the Shade of a Tree* along the way. You *Walk Over Uneven Ground*, which provides wonderful balanced strength to your muscles, which indoor gym equipment seeks to mimic. You *Walk Over Fallen Logs*, *Pay Attention to the Intensity of the Sun*, *Keep an Ear Out for Animals*, *Recognize and Be Recognized by a Deer*, *Encounter Bugs*, *Kill Mosquitos*, *Gaze onto Distant Nature from a Special Spot* (Figure 2), *Watch Birds*, and *Stand on Mountain Top*. Of course, that is a very brief list of the forms of interaction along the way. Then, once you are at your destination spot, you have to get home. This is unlike a treadmill where you are always tempted to say "enough, I'm so tired, I'm just going to stop right now!" Thus, this keystone interaction pattern engenders hundreds of other patterns, as it gets you into motion, and likely a little further than you might have expected.

Figure 2. Interaction Pattern: Gazing Onto Distant Nature from a Special Spot (Photographs by Tom Blackwell, Adam Jones, and Haakon Herlik Kristiansen).

2. Walking Along the Edges of Nature

Edges are interesting places. Put two different ideas together and you can have something totally new. Biology and chemistry: biochemistry. Neuroscience and psychology: neuropsychology. So, too, in nature it's often where the edges meet that the action lies. It is the fertile ground where the ocean meets the shore, and the fish and tidal life abound; or where forests meet the meadow, and black bears walk. Often trails exist between edges of ecosystems, such as between a forest and meadow. When that happens, and if the trail is in on the meadow's edge, there is usually an optimal distance it keeps from the woodland. If it is too close to the edge, you will feel undue uneasiness, perhaps because you are not able to ascertain if there is wildlife within the vegetation that can hurt you, even as you feel the desire to be close to the edge, perhaps because of the visual protection the woods afford from predators in the open area. You will see this psychology play out in open flat grass parks, where people do not often just walk into the middle of such an area and have a picnic exposed like that. No, they will find an edge; it is more comfortable. There is the miles of paths along both sides (edges) of the Charles River that separates Boston and Cambridge, and which are heavily used by walkers and runners. Many lakes in urban settings have paths around them, and are used heavily. At Sea Ranch in Northern California there is over 10 miles of an ocean bluff top trail. There is a reason that people go there to vacation. It is a powerful and very alive edge of the world. Many of the classic mountaineering routes in the world follow the ridges (edges) of the mountain to the top, such as the West Buttress on Denali (Figure 3) and the West Ridge on Everest. If you are in a city with some hills, you can walk a street that traverses a ridgeline. Some edges are highly dynamic, such as the edge between sunlight and shade. Wherever you are, you can find an edge and walk it. You will feel a little of that aliveness.

3. Movement Away From Human Settlement, and the Return

In Paleolithic times, hunters would leave nomadic campsites and go out in search of animals, and gatherers would leave in search of roots, tubers, nuts, berries, and other plant life. The further out they went, the more they left the safety of the larger group. Sometimes hunters would hunt alone. On the African Savannah, Bushmen would on occasion run down a bull eland in 120-degree heat. According to Thomas (2006), the hunter could not match the eland for speed, for the eland sprints at 35 miles an hour. But eventually, after many hours of being chased in the heat, the eland overheats and can run no more. Both hunters and gatherers would then return, hopefully (but not always) with their bounty, looking forward to the re-union with their group and loved ones, to the warmth of the fire, fullness of belly.

Still, today, we enact aspects of this interaction pattern every time we leave the comfort and safety of our homes and venture out. When you are in your teens and twenties, this pattern can be more easily instantiated in wild ways, covering vast distances out into remote places. In old age, there is a beautiful domestic instantiation of this pattern: you open the door and walk outside. Maybe you need a cane. Even if only for one block out, and then back, that's enough because once you engage this keystone interaction pattern, it sets into motion, or at least makes possible other deep, immediate, alive interactions with nature, in ways that staying inside (e.g., on a treadmill) can never duplicate. In a single block of walking out, an elderly person can still engage the keystone interaction pattern of *Walking to a Desired Destination in Nature* and *Walking Along an Edge*, and enact some of the complementary interaction patterns described above. You can experience that beautiful feeling of needing to take care of yourself while you are "out"—you do not want to fall or get hurt—and being able to do so.

Sometimes urban planners or National Park planners like to make it easy and "equitable" for people to get to a beautiful spot, perhaps under pressure from the public itself. Thus they put a road right up to the destination. Roads have their place, and can create affordances for human-nature interaction. Yet, roads often come at costs to human-nature interaction, which too few people recognize; and so we need language for the costs as well as the benefits. There is a lovely trailhead in Marin County, California where the parking lot is a couple of miles from the ocean. The trail is actually a drivable dirt road; but the planners wisely block it to cars, and permit access only on foot, bike, or horseback. What this wonderful planning decision does is to allow for this keystone interaction pattern to be enacted, and it is, joyously, by hundreds of people most every day of the year.

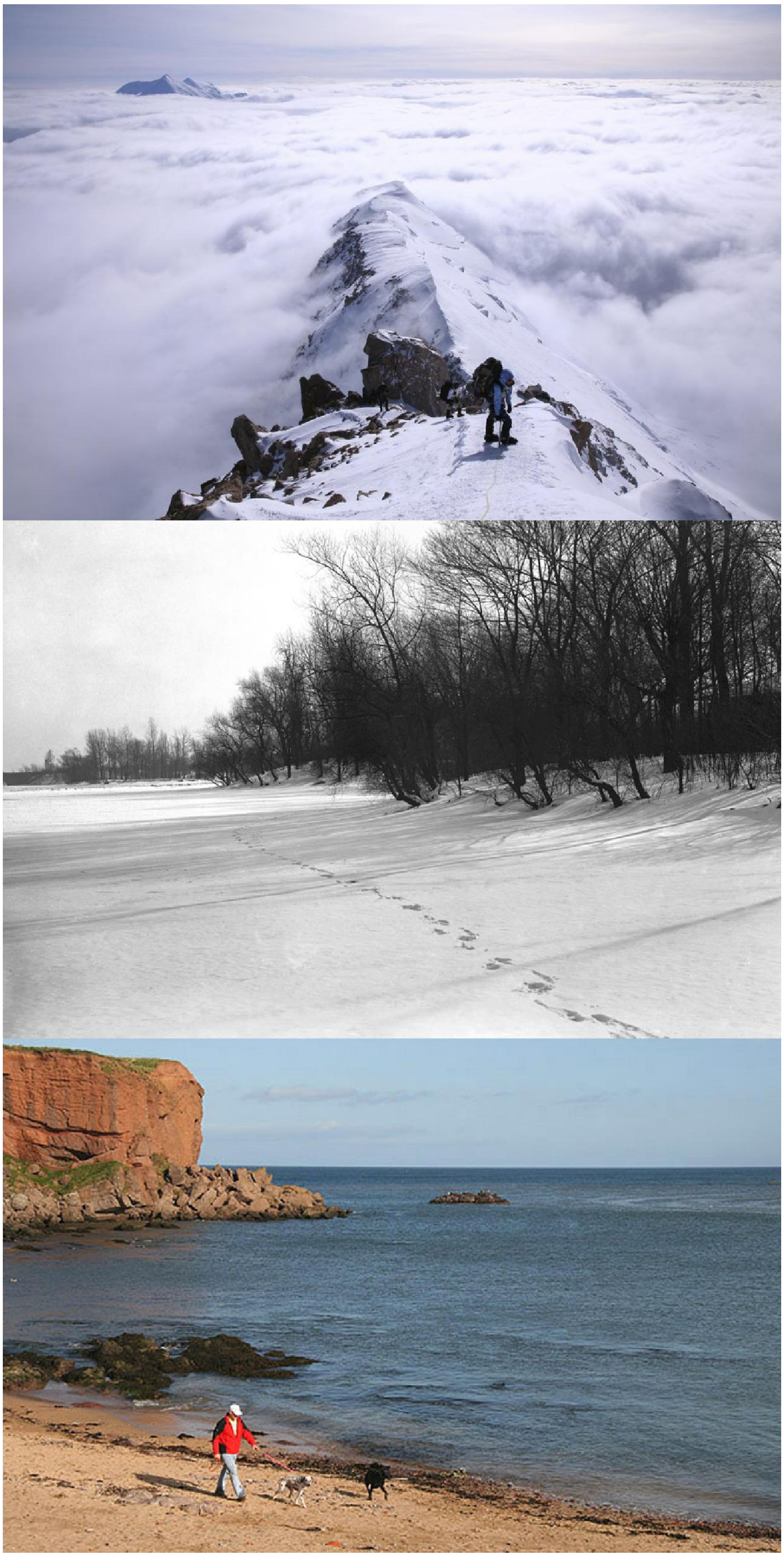

Figure 3. Interaction Pattern: *Walking Along the Edges of Nature*
(Photographs by Johnathan Esper, The Field Museum Library, and Walter Baxter).

Designing for such interaction patterns helps to foster sustainable environments: those where people want to be because they can feel themselves flourishing.

INTERACTION PATTERN DESIGN FOR URBAN SUSTAINABILITY

One starting point for the ideas of this paper is that interaction with nature is beneficial for people, physically and psychologically. The research literature shows, for example, that interaction with nature can reduce stress (Berto, 2014), reduce depression (Taylor, Wheeler, White, Economou, & Osborne, 2015); reduce aggression (Younan, Tuvblad, Li, Wu, Lurmann, Franklin, et al., 2016); reduce crime (Kuo & Sullivan, 2001); reduce ADHD symptoms (Kuo & Taylor, 2004); improve immune function (Rook, 2013); improve eyesight (He, Xiang, Zeng, Mai, Chen, Zhang, et al., 2015); improve mental health (Bratman, Hamilton, & Daily, 2012), and increase people's social connectedness (Holtan, Dieterlen, & Sullivan, 2014). Reviews on these subjects are offered by Hartig, Mitchel, de Vries, & Frumkin, 2014; Frumkin, 2012; Frumkin et al., in press. If we agree—based on such benefits, for example—that interaction with nature is highly desirable, then interaction pattern analysis offers a new approach for designing sustainable built environments and urban infrastructures, with an emphasis on human flourishing. We call this approach *Interaction Pattern Design*.

A straightforward way to engage in Interaction Pattern Design is to begin with answering these types of questions:

- Specify the scope of your site. You might be looking at designing a school yard or city park, or landscaping an outside mall, or providing a master plan for an entire region.

- What forms of interactions between humans and nature can occur within the scope of your site, and where do they occur? You can generate bottom up by looking at what people do, or asking them about their meaningful nature experiences at the site, or by conducting focus groups. You can also generate top down by drawing on the existing interaction pattern literature, and being particularly attuned to the affordances of your particular site. For example, where are the edges between ecosystems? Are they between forest and meadow, or between a wetland and roadway? Where are the big trees? Big vistas? Where is the water? Promontories? What areas allow the senses—especially more than vision—to be engaged?

- When do the interactions occur? The sunrise happens in the morning, of course: are there places to experience it? The encounter with a Barred owl happens most likely at dusk: are their paths through their habitat? How do the interactions change between the seasons?

- With whom do they occur? Nature interaction can occur by oneself; but it is also often with others, as with children with parents, and friends with friends, or in the workplace.

- Why is this form of interaction important? Answering this question can help you argue for specific designs, and help you see those you have yet to see. In a hot landscape, for example, the shade of trees provides relief.

From here, you can begin to characterize many possible interactions, and ways in which they build on one another or happen simultaneously. Then you can begin to offer sketches of designs that enable such interactions.

As a case in point, the first Author with P. Hasbach engaged in a consulting relationship with the international architectural firm NBBJ and their client Google, with the goal of enhancing the design of a new corporate campus for Google in the San Francisco Bay Area (Davidge, Montgomery, Sturgeon, & Garvin, 2013). We led a day-long workshop with about 25 of their architects on site. We presented the basic ideas of interaction patterns, and then walked the site, and as a team generated hundreds of specific interaction patterns that could be enhanced or enacted with the right campus design. For example, adjoining the corporate site, just on the other side of the property, separated by a high chain link fence, there was a paved bikeway/corridor that extended for tens of miles. For security purposes, it had been proposed that no entrance would be built on that side of the campus. But one of the affordances of the extended corridor is that it could allow people on their lunch break to go for a walk or bike ride out and back—as in the interaction pattern discussed above, *Movement Away From Human Settlement, and the Return*. Enacting this interaction pattern during the day would not be possible if fifteen to twenty minutes had to be spent going around the other side of the corporate campus, so as to link up with the corridor. This design feature (access on the corridor side of the campus) needed to be argued for, which benefited from a nature language, based on the constituent parts of interaction patterns. A few of the other interaction patterns that led to design ideas, of hundreds generated, focused on edges: the edges of where grasslands met shrubs; the edges of where ecosystems changed; the edges of the day (sunrise and sunset); the edge of a precipice; the edge of a balcony. Architects spoke of a nature "mapping" from the "edges of nature" to the "edges of one's mind". Google is seeking people to create, to innovate, to go where no one has yet gone—which is wild space—and to do that one first has to get to some edges, in order to go beyond.

In another application, the first Author engaged in a consulting relationship with Harmony Institute, which is affiliated with Harmony Development, a many thousand-acre housing development in Central Florida. Our goal was to provide an initial interaction pattern analysis of the human-nature interaction that nature at Harmony affords. Some of the keystone interaction patterns described earlier came out of this body of work. This descriptive work leads to new ways to see and to articulate what works in housing developments. For example, one of the members of Harmony spoke of his enjoyment of the public nature-inspired art that they installed in their development. One installation caught our eye because of its visual beauty. And then we saw how it provided a domestic form of a timeless essential form of an interaction pattern.

We called this interaction pattern: *Navigating by Landmark* (Figure 4). The wild version is in the first photo. In the days of the pioneers heading west through Nebraska, along the Mormon, Oregon and California trails, they would use the landmark known as Chimney Rock as a means for navigation, and would let people know of their location in reference to it. You can hear this interaction pattern enacted every time someone says something like "head north once you pass the huge oak tree," or "head upstream at the creek" or "take a left when you reach the gardens."

A beautiful domestic (artefactual) version of this interaction pattern can be seen with the butterfly exhibit at Harmony. As the member spoke to us, he said: "it helps people locate where they are". "It is one thing to say 'turn left at the intersection'; it is another thing to say 'turn left at the butterfly'. So it is kind of a different way of getting around town".

And then there are potentially "perverse" forms of more wild and domestic forms of interaction patterns. If "perverse" is too strong of a word, then we can soften it. But the idea is that when the interaction does not have healthy forms of expression, the pattern still gets enacted but in ways that may not be conducive to human health and human wellbeing. For example, if you are in this part of Manhattan and you are trying to meet someone for the first time in a public place, it might be most effective to say, "I'll meet you at the McDonalds at 5:00 PM". The logo is instantly recognizable throughout the world: fast food, high calorie, low quality, fats and sugars, burger nation.

Figure 4. Interaction Pattern: *Navigating by Landmark*
(Photographs by Allen Stutheit, Harmony, and Sardaka).

THE RELATION BETWEEN BIOPHILIC DESIGN AND INTERACTION PATTERN DESIGN

Our ideas of a Nature Language and Interaction Pattern Design overlap some with biophilia and biophilic design. Biophilia refers to that innate affiliation that people have with nature, grounded in natural selection and the evolutionary history of our species (Wilson, 1984; Kellert & Wilson, 1993; Kahn, 1999). In broad strokes, biophilic design draws on this theoretical perspective, and focuses on maintaining, enhancing, and restoring the beneficial experience of nature in the built environment (Kellert, 2005; Kellert, Heerwagen, & Mador, 2008). Kellert (2005) proposes the following elements and attributes of biophilic design:

- Environmental features (e.g., air, water, sunlight plants, animals).
- Natural shapes and forms (e.g., shell's and spirals, arches, biomimicry).
- Natural patterns and process (e.g., transitional spaces, fractals).
- Light and space (e.g., natural light, filtered lights, spatial variability).
- Place-based relationships (e.g., historic connection to place, indigenous materials, landscape ecology).
- Evolved human-nature relationships (e.g., prospect and refuge, fear and awe, exploration; reverence).

Interaction Pattern Design also focuses on the importance of nature in our everyday lives, and grounds that need theoretically in evolutionary accounts of our species. But while Interaction Pattern Design welcomes all that biophilic design offers, it focuses on creating and enhancing the range and depth of interaction with nature. For example, imagine two fountains designed for an urban environment. One looks beautiful, and has the biophilic design properties of environmental features (e.g., water, sunlight), natural shapes and forms (e.g., natural stone), and natural patterns (e.g., fractals). Yet what if the person's main access to the fountain is only through the sense of sight and hearing, as in the Saint Peter's Square Fountain (Figure 5)? There is little in biophilic design that pushes and prods the designer to engage people more directly. Rather, from the standpoint of Interaction Pattern Design, the many biophilic affordances of a fountain call out for more direct interaction with it. What might that look like? One example, of many, can be seen in the Keller Fountain (Figure 5) in Portland, Oregon (USA), which offers many forms of interaction beyond vision and hearing, such as *Lying on Wet Rock Above Drop Off; Sitting on Edge of Waterfall; Standing in Waterfall; Walking in Waterfall.* In addition, in such a fountain you can *Wade in Water; Splash Water on Face; Splash Water on a Friend; Climb up Waterfall*. Notice that with the lens of Interaction Pattern Design, you do not just see water and people. You focus on the verb, such as swimming, climbing, lying, sitting, wading, and relaxing. And you focus on the reasons that are meaningful to people to engage in these forms of interactions. It might be for mental restoration: a break in the midst of a stressful day. It might be physical health. It could be all of those. It could be rehabilitation from an injury. If there is a family there, it might be a convivial gathering place for them to interact in the context of an activity. Thus in these ways,

Figure 5. Saint Peter's Square in Vatican City; Keller Fountain, Portland, OR (Photographs by trukdotcom and Hagar66).

Interaction Pattern Design seeks to provide for meaningful, often daily, and sometimes deep connection with nature.

CONCLUSION

Many environmentalists are focused on "saving" nature, but if people do not interact with nature, those efforts will not be enough. The reason is that without interaction nature remains too easily an abstraction, as something "out there," perhaps valued in some intellectual way; but when pitted against increased development, jobs, and money, nature does not (often enough) carry the day. It is an insidious cycle, because the more nature is destroyed, the less nature there is for people to interact with. Then, as people interact less with nature, they care about it less, and allow for its destruction, or participate in it. Which leads to even less nature in human lives, and more resource extraction, more destruction.

How can we not only stop this cycle, but also reverse its course? We suggest one answer lies on focusing on where the problem originates: at the point of interaction (or lack of). Thus in this article we have emphasized human-nature interaction as constituents of a nature language. Our research lab is currently using interaction patterns and a nature language to describe children's interactions with nature in a forest preschool (Kahn & Weiss, in press), as well as how visitors interact with the largest park in the city of Seattle. In this article, we also put forward a design approach, based on interaction patterns that can help people—all of us—name what we already do, and more importantly rediscover and recover what has been lost to us, but which still is an essential part of our human nature. In turn, interaction pattern design, which extends biophilic design, can be used to generate and build a more sustainable urban environment in the sense that as we find ways to bring more human-nature interaction into the cities, there is by definition more nature—and a healthier and more vibrant people—that is sustained.

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A Psychological Approach to Olfactory Information as Cues in Our Environment

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ABSTRACT

Landmarks, objects helping us to orientate ourselves through space, have a pivotal role in wayfinding and navigation research. They help to structure space and especially our surrounding environment, e.g., "Turn right at the statue". This theoretical contribution provides an overview of important factors in landmark-based wayfinding and discusses an often-neglected sense: olfaction. We argue that the extent to which olfactory information might impair or facilitate spatial orientation depends on multiple factors that need to be investigated. Such factors could be cognitive saliency and multi-modal information integration. This is all the more important when we get older and/or suffer from certain deficiencies and illnesses, such as eye-degeneration, dementia or depression, e.g., when designing and running nursing homes. It is an issue at the heart of biophilic design: we need to structure our environment so that it matches our needs but also incorporates our perceptual and cognitive capabilities.

Keywords: navigation, landmark-based wayfinding, salience, olfaction, multimodality

INTRODUCTION

Finding our ways in everyday life, from our apartment to work, from our work place to the grocery store, and so forth, is an ability that we take for granted as long as it works properly (for an anthropological approach see Istomin & Dwyer, 2009). The complex cognitive processes related to these tasks are rarely appreciated. Spatial orientation is not just wayfinding from A to B—in a building or in the larger environment—but also includes other instances like searching for a book on a shelf or looking for a certain link on a website. Moving objects and interacting with them are also challenges of spatial planning and action. Thus, spatial information processing requires many different cognitive processes in order to successfully get from initial perception—of a feature, building, environment—to the adequate action, namely attention, imagery, working and long-term memory, experience and knowledge, reasoning, problem solving, decision making, and the like.

The human brain is extremely capable of encoding, organizing, storing, revising and retrieving spatial information in order to allow for successful spatial orientation (for an overview see Kitchin & Blades, 2002). Our memory systems process and store directional information as well as place locations in egocentric, i.e., subject related, and allocentric, i.e., object related, reference systems (e.g., Burgess, Spiers, & Paleologou, 2004; Coluccia, Mammarella, De Beni, Ittyerah, & Cornoldi, 2007) represented as cognitive maps (e.g., Hermann, Schweizer, Janzen, & Katz, 1998; Thorndyke & Hayes-Roth, 1982; Tolman, 1948). One specific example of such spatial information are so-called landmarks, which are a core aspect in human wayfinding (e.g., Epstein & Vass, 2014). For this reason, we will focus on landmark information and not on additional processes such as proprioceptive or vestibular information.

LANDMARK-BASED WAYFINDING

Landmarks

What is a *landmark*? The term landmark is not strictly defined, at least in the cognitive sciences. The Dutch neuroscientist and psychologist Albert Postma once stated that "I use the term landmark quite loosely" (personal communication, November 10, 2010). It remains unclear whether landmarks can be 2-*D* representations, e.g., signs, or have to be 3-*D* objects. In general, it is widely accepted that landmarks are constituted by natural objects, such as trees, rivers, mountains, or by man-made objects, such as buildings as well as interior objects, e.g., a sculpture in a room, that can be used as an orientation aid (for an overview, see for example Lynch, 1960; Golledge, 1999). From this description, it immediately becomes clear that the focus concerning landmarks lies on visual features and how these objects visually stand out from their surroundings (Lynch, 1960; Presson & Montello, 1988). However, as we will later see, such visual features are sometimes overemphasized.

Inherent features of landmarks

The amount to which landmarks stand out from their environment is called salience. In the perceptual sciences, this salience can easily be measured as contrast, i.e., luminance/color. However, in the cognitive sciences such contrast measures are rather difficult with respect to concepts such as familiarity/famousness and function of a building. In other words, everything that is not directly represented within a sensory modality is rather difficult to grasp with contrast measures. Thus, landmark salience in spatial cognition is a bit more abstract but there is much empirical evidence for a useful distinction available. An overview of the different landmark saliences can be found in Caduff and Timpf (2008). The Authors do not only emphasize *perceptual*—e.g., is the building tall and illuminated—and *structural* aspects (Sorrows & Hirtle, 1999; Raubal & Winter, 2002; Klippel & Winter, 2005)—e.g., is it built on a prominent place—but also introduce another aspect: *cognitive* landmark salience also known as s*emantic* landmark salience (e.g., Sorrows & Hirtle, 1999). It describes the meaning or function of a building, its famousness, but also the idiosyncratic relevance for the observer; e.g., the house of a loved one. Please note that, for better readability, we from now on use the term cognitive landmark salience when we speak of cognitive and/or semantic landmark salience. Figure 1 demonstrates a combination of high visual landmark salience, i.e., architectural features, and cognitive landmark salience, i.e., function of a building; clock-tower, TV-tower, museum. The so-called global landmarks (clock-tower and TV-tower) may be seen from a farther distance and many different viewpoints. They also represent marks or brands of a city, e.g., Big Ben on a postcard of London. If you take out such famous landmarks, the city scene becomes much harder to be recognized and many people are not able to name the city correctly anymore (Hamburger, Trillmich, Baier, Wolf, & Röser, 2014). Cognitive landmark salience is further of great importance, since it also incorporates the cognitive abilities and preferences of the observer/navigator.

Figure 1. Well-known landmarks. These are examples for the importance of cognitive landmark salience. Please note that taller buildings, such as the Big Ben on the left or Berlin's TV tower may also serve as so-called global landmarks, since they can be seen from many different places and over larger distances in comparison to more local landmarks such as the Bode-Museum in the center of the right image.

The problem with focusing on vision

We have seen that, even though saliences are not as accurately defined as in other research domains, we do have valuable and adequate concepts for defining and measuring them. But, there is still a problem that we have already mentioned: the emphasis on visual attributes—i.e., color, texture, size, and shape—and visual contrast—in terms of *differentiability* rather than luminance or color contrast. Even though other attributes such as auditory and olfactory information have been proposed as valuable information in landmark-based wayfinding (Caduff & Timpf, 2008), there is hardly any information about the appropriateness of auditory and olfactory information in spatial orientation. Research on acoustic information for spatial orientation is rather limited (e.g., Blenkhorn & Evans, 1997) but demonstrates that sound emitter are subjectively experienced as potentially useful (Baus et al., 2007). In contrast to more permanent acoustic landmarks, i.e., noise at a construction site or factory, many devices emit their signal often temporarily for a specific purpose, e.g., sound beacons for guiding people acoustically during an emergency. Boer and

Withington (2004) could show that such guidance does only work well when subjects receive explicit information about the purpose of the sound beacons. In case they prove to be useful, different application fields may benefit from acoustic landmarks or sound beacons, such as firefighting (Walker & Lindsay, 2006), safety improvement and awareness enhancement in aviation environments (Simpson, Brungart, Gilkey, & McKinley, 2005), and video surveillance (Höferlin, Höferlin, Raschke, Heidemann, & Weiskopf, 2011).

To the best of our knowledge, there are only a few studies available in regards to olfactory information in wayfinding (see below). The question that logically follows and which was already mentioned as part of our empirical investigations (Karimpur & Hamburger, 2016) is: how much can olfactory information contribute to successful spatial orientation?

Based on recent research, we may state that visual landmarks are sometimes overemphasized and that they are overrepresented in empirical landmark research (Hamburger & Röser, 2011; 2014). We were able to demonstrate that other components than visual features can significantly influence the extent to which a landmark facilitates wayfinding performance. The structural landmark salience has been shown to be of great importance. As long as an object can be *recognized,* we can facilitate successful orientation, for example, by positioning the landmark before an intersection in direction of turn (Röser, 2015; Karimpur, Röser, & Hamburger, 2016). However, it should be noted that route learning without landmarks is also possible and a quite frequently used strategy (not further discussed here). Landmarks are used when they are available in the environment.

Unimodal and multimodal landmark processing

If *other* components than visual features can facilitate the wayfinding performance, why should not *additional* components act in a similar manner? For example, we could add auditory features to a visual landmark. This leads to the issue of multimodality. Due to the above challenges and the research results, we first set out to investigate the role of unimodal auditory landmarks in landmark recognition and wayfinding. We could show that auditory landmark information is as well suited for spatial orientation as visual information (Hamburger & Röser, 2014; Karimpur & Hamburger, 2016). We could also show that it is possible to learn landmark information in one modality and retrieve it from another at no additional costs, e.g., learning the "meow" of a cat and matching it to an image of a cat at the time of retrieval (Hamburger & Röser, 2011). Furthermore, participants are much better when learning and retrieving semantically congruent information, e.g., "meow" and cat, in comparison to incongruent landmark information, e.g., "meow" and pig (Karimpur & Hamburger, 2016). However, there is more to that. For example, apart from Braille, verbal information can either be given *visually* and/or *acoustically*, as for example realized in mobile navigation systems. Since we already know about the influence of audio-visual combinations (Karimpur & Hamburger, 2016), it is now important to extend this line of research and address verbal landmark information within the visual (written) and auditory (spoken) domains. This is especially of importance for signage systems within buildings and urban environments, e.g., traffic engineering.

We could show that auditory landmarks are valuable in spatial orientation and that other modalities besides vision can successfully be used in spatial orientation. Therefore, the question remains, in accordance with the landmark salience definition of Caduff and Timpf (2008), whether the olfactory modality is also suited for processing navigationally relevant landmark information.

OLFACTORY INFORMATION

In the literature it has often been suggested that humans, possessing about 400 different smell receptors, can discriminate between 6,000 and somewhat more than 10,000 different odors (for a review see Gilbert, 2008). Numbers vary, but any discrimination of several thousand odors (Gottfried, 2006) breaks down when subjects have to name an odor (Cain, 1979). However, a recent study challenged these traditional views and estimated that humans are able to discriminate more than one trillion olfactory stimuli (Bushdid, Magnasco, Vosshall, & Keller, 2016), thus outperforming vision (2.3 to 7.5 million colors; Nickerson & Newhall, 1943; Pointer & Attridge, 1998) and hearing (about 340,000 different tones; Stevens & Davis, 1938) by far. One major problem in this research field is that you cannot exactly measure the capabilities of discriminating odors (objectively), which, in contrast, is possible for vision (wavelengths 390–700 nm) and sound (20–20,000 Hz; Bushdid et al., 2016). For more detailed information on odor perception and discrimination, please see the recent review by Majid, Speed, Croijmans, and Arshamian (2017).

The contribution of olfactory cues to spatial orientation

Research on the role of olfactory information in spatial perception is available (e.g., Vilaplana & Yamanaka, 2015) but rare with respect to spatial orientation (e.g., Gottfried & Dolan, 2003). When we look into the research on landmarks and landmark-based wayfinding in combination with olfaction, there are only few publications to be found. These are mainly concerned with desert ants (Buehlmann, Hansson, & Knaden, 2012a, b; Steck, 2012; Steck, Hansson, & Knaden, 2009, 2011) and rats (e.g., Rossier & Schenk, 2003) but not primarily with human participants. However, as we have already seen, the topic is an important one. In addition, the number of scientific contributions in this field is currently increasing, also indicating the importance of the topic. The Digital Olfaction Society, for example, held a Congress in December 2016 with a contribution by Ryo Wako from the University of Tsukuba, Japan on “The effect of odor on the perception of space”. Furthermore, a multidisciplinary research group currently tries to *crack the olfactory code*. This is a multimillion dollar project funded by the National Science Foundation (NSF) and the White House BRAIN Initiative in the United States of America. For example, John P. Crimaldi from the Department Civil, Environmental and Architectural Engineering at CU Boulder and his colleagues study the temporal and spatial structure of odors to extract—in the long run—spatially relevant information (*The architecture of smell*, 2017). This leaves the positive impression of a research area in the early stages of development rather than one that has been unsuccessfully addressed.

Are humans capable of processing and integrating olfactory information for spatial orientation? If so, in which way? Can they be regarded as “olfactory landmarks” whose inherent properties can be described in terms of their perceptual or cognitive salience, or both? One possibility to embed olfaction within the concept of landmark-based wayfinding is cognitive landmark salience: creating a link to affective responses. In a recent study, we were able to show that affective responses play an important role in wayfinding (Balaban, Karimpur, Röser, & Hamburger, 2017). For example, when subjects saw landmarks that were associated with negative feelings, they showed improved wayfinding performance even one week after. Interestingly, such affective responses can also be evoked by olfactory information (Bensafi et al., 2002). Therefore, it should be possible to identify certain smells or certain groups of smells and to link them to spatial information, for example, by means of cognitive landmark salience.

The problems with "olfactory landmarks"

Humans can allocate their attention and thus their sensory modalities where they are needed. This can, for instance, be realized with visual and auditory information (sound beacons: Walker & Lindsay, 2006; spatial images from 3D sounds: Loomis, Lippa, Golledge, & Klatzky, 2002). But, we are not able to smell three-dimensionally. Olfaction is a rather *diffuse* sense. Locating where a certain odor came from is almost impossible for humans (e.g., Radil & Wysocki, 1998). Additionally, we should bear in mind that such fuzzy information could be interpreted as noisy input. Since we integrate multimodal information depending on their statistical reliability (Ernst & Banks, 2002), olfactory information could simply be disregarded as a result of being unreliable.

Further, olfactory information alone might not be very helpful for spatial orientation. However, it might be possible that an odor at an intersection can successfully be linked to a certain direction you want to go. For example, the smell of fresh bread indicates a bakery and can tell you in which direction you need to turn. In theory, any perceptually accessible entity, if permanently present and consistent, may serve as a landmark by allowing for a connection to spatial information, e.g., "turn right". This constitutes one problem with olfactory information: being permanently present and consistent.

There is another problem that we are confronted with. How well are we able to *identify* a certain smell? The term identification here refers to the process of connecting it semantically to the information it carries, e.g., the smell of a strawberry linked to the color red and the concept of a fruit (=semantic network). We are used to linking olfactory information to visual or auditory information. Gottfried and Dolan (2003) have for example, demonstrated that a combination of olfactory information and visual information leads to increased odor identification performance. Thus, it is also possible that cross-modal information processing of olfactory information and auditory and/or visual material may enhance performance in spatial orientation as well.

The first problem (presence) is a problem concerning application-oriented research. For example, more and more grocery stores turn to "scent-marketing" and use odor-releasing devices in their produce departments. The second problem (identification) might not even be a problem at all for the following reason. Maybe discriminating olfactory information is sufficient and there is no need to identify olfactory information in detail. It would allow us to simply recognize a smell without *naming* it and to associate it with a direction. Indeed, this is what landmarks do: they serve as objects in our surroundings that allow us to associate them with other information for spatial orientation, without necessarily being able to name them.

How to investigate the usefulness of olfactory cues in space

The main question here is to what extent, if at all, can olfactory information really facilitate human landmark-based wayfinding? Maybe it is just a supplement for other sensory modalities (see above). As a first step, it is important to have a large number of odors at hand that can reliably be recognized (but not necessarily identified) by humans and test mere recognition. This is crucial since recognition precedes any associations.

Currently, we are running experiments, in which we investigate associative learning, i.e., linking a certain smell to directional information, and recognition performance ("Has this odor been presented to you in the previous learning phase or not?"). In these experiments, participants are passively led through a virtual maze with orthogonal four-way intersections and/or T-junctions. At every intersection, they are presented with a certain odor. In previous studies, the given landmark information has either been visual and/or auditory (e.g., Karimpur & Hamburger, 2016). Now, participants are confronted with olfactory information at the points where a route decision in form of a turn to the right, to the left, or straight is required. Subsequently to this learning phase, they have to solve a wayfinding task in which they need to provide the correct directional information (right, left, straight), based on the given olfactory information and a recognition task in which they have to indicate whether a certain odor has been presented in the previous learning phase or not. These test the recognition as well as the associations between odor and spatial information. The odors in the current experiments have been retrieved from a piloting experiment in which participants should identify 45 different odors. The 24 with the highest identification rates (above 20%) have been selected for the main experiments. Examples are lemon (with the highest identification rate), lavender, basil, and disinfectant. Thus, the odors stem from sources in our everyday lives, i.e., kitchen/restaurant, bathroom, supermarket, hospital/nursing home, etc.

Preliminary results from the first behavioral experiment look as follows: participants are performing well in recognizing the olfactory information they have been confronted with. In addition, they are also able to successfully associate directional information with a certain odor. Performance in both tasks is significantly above chance level. In addition, participants are also significantly better in recognition and in choosing the correct direction in comparison to odor *identification*, i.e., naming it correctly. These findings are in line with the above research literature on olfactory information processing and the problems with olfactory information.

Three major research questions or branches now arise from the above:

1. If olfactory information can be successfully associated with directional information, we need to first compare unimodal processing of olfactory information with visual, verbal, and acoustic landmarks. This helps us to determine the value of olfactory information in spatial orientation on its own. Since most information our perceptual and cognitive system has to process is only available in multiple sensory modalities, we then need to systematically investigate and compare multimodal information processing, i.e., visual + olfactory vs. verbal + olfactory, and so forth. Therefore, it is important to know which type of information combination is processed best, remembered for a longer period, and so forth.

2. Since we already indicated that olfactory information may increase the value of other sensory modalities, it will be necessary to not only address research questions on multisensory integration in detail, but also questions about modality switching and switching costs (Hamburger & Röser, 2011). How is, for instance, olfactory information made available in other modalities? Does the smell of a strawberry automatically generate a mental visual image of the fruit? If this is the case, will the neural response represent the correct information (see also below in the section on olfactory information and neuroscience)?

3. Whenever we combine two stimuli from different modalities, we need to ask "how should they be combined?" Two of several relevant hypotheses on this issue are the *congruency* and the *novelty hypothesis*. The *congruency hypothesis* claims that multimodal information is processed and remembered best when it matches semantically in different modalities, e.g., smell of a strawberry and picture of a strawberry. This hypothesis is intuitively plausible. The *novelty hypothesis* states

that incongruent information, e.g., smell of a strawberry combined with an image of a banana, works much better, since this is a new combination of information that draws on attentional resources. It requires additional capacities from working memory (no automatic processing), which in turn leads to a deeper processing of the information and better consolidation in long-term memory. First empirical evidence from object identification with visual and olfactory (Gottfried & Dolan, 2003) and wayfinding research with visual and acoustic information (Karimpur & Hamburger, 2016) supports the congruency hypothesis. However, systematic research on olfactory information in human wayfinding is not available yet.

FUTURE RESEARCH ON OLFACTORY INFORMATION

Behavioral studies in and outside the laboratory and virtual reality experiments

Behavioral studies in the laboratory, as demonstrated above, are an important tool for the investigation of spatial orientation. However, they are often criticized for lacking ecological validity. The problem with real-life experiments is, however, that they often prove to be not very economic, e.g., time-consuming, with low experimental control, e.g., landmarks in the environment are already present and you cannot manipulate or erase them. These kinds of experiments have high ecological validity but very low experimental control and are not economic at all. One possibility to overcome most of these shortcomings—at least partially—is the use of modern virtual reality technology, e.g., with head-mounted displays. Designing and then exploring virtual rooms and buildings is common in design and architecture. We recently provided a brief overview on the advantages and disadvantages of action video games and virtual environments for psychological research (Karimpur & Hamburger, 2015). Further, we discussed the topic of ecological validity also in a recent VR study (Karimpur & Hamburger, 2016). This technology currently seems to be the silver bullet in the research field of spatial orientation. For the systematic investigation of olfactory information, it will be important to connect odor-releasing devices to the (visual) virtual reality system in order to provide an even higher level of immersion. Such high level of immersion may also prove to be useful in the field of architecture and interior design. When we are able to combine visual virtual reality with odor-releasing devices, we may simulate advantageous and disadvantageous settings and experiences on a behavioral level.

Olfactory information and neuroscience

In experiments in which landmarks are provided in a single modality, e.g., hearing a church bell, the information is made available by the brain in different sensory modalities, e.g., visually imagining the church. It has been demonstrated that activation in the auditory cortex, when hearing certain sounds, leads to activation in the visual cortex, resulting in mental images (Tranel et al., 2003). The opposite is not necessarily the case and findings are ambiguous. Activation of the visual cortex during lip-reading leads to activation of the auditory cortex (Calvert et al., 1997) while physically presented images are accompanied by neural activity in the auditory cortex of deaf but not healthy participants (Finney, Clementz, Hickok, & Dobkins, 2003). This may indicate a directional bias with respect to how information is transferred from one modality into another. Further, Janzen and van Turennout (2004) demonstrated that the hippocampus and the parahippocampal area differentiate between important and unimportant objects/locations. Landmarks at decision points were associated with higher activation in the hippocampus and parahippocampal areas, even without conscious recollection of these objects or directions (for an overview of possible neural systems involved in landmark-based wayfinding see Epstein & Vass, 2014; for an overview on the role of the hippocampus in spatial orientation and memory see O'Keefe & Nadel, 1978). This is evidence for information being processed in different modalities even outside conscious awareness. In this domain, olfactory information may not be neglected any longer.

CONCLUSION

Why is the above research so important? And, more precisely, why is it important for interdisciplinary research in psychology, neuroscience, and biophilic design?

Let us give an example for clarification. Modern technology allows us to process more information in a short period of time. This is a blessing on the one hand, but also a curse on the other. Smartphones, computers, navigation systems, nursing robots, and the like facilitate our daily lives. We are able to transfer many operations from our mind/brain to external devices. Some 20 years ago people remembered telephone numbers, today they are stored in a smartphone and we are lost without it; some 15 years ago people frequently used road maps, today they mainly follow route instructions of a navigation aid. All this is known as *extended cognition* (e.g., Clark, 2008; Clark & Chalmers, 1998); it reduces cognitive load, which is useful in certain situations to spare working memory resources. Further, we know that our perceptual system, especially the visual system, becomes worse during the ageing process (e.g., decline of useful field of view: Ball, Beard, Roenker, Miller, & Griggs, 1988; loss of contrast sensitivity in high spatial frequencies: Crassini, Brown, & Bowman, 1988). Additionally, our cognitive system is affected in that working memory capacity (Baddeley, 2003; Baddeley & Hitch, 1974) and attentional resources decline as well. Even more on the downside, we know that certain illnesses such as depression, schizophrenia, posttraumatic stress disorders (PTSD), and others are accompanied with working memory deficits (e.g., Smith & Kosslyn, 2007). Based on the above presented and discussed findings it may be assumed that landmark-based spatial orientation can be improved by altering the salience of reference points in our environment. Possibly, olfactory information may do its job in this context as well. Odors may prove to be very useful for nursing homes and clinics. Patients with dementia suffer not only from age-related degeneration processes but also from deeply decreased memory performance and attentional deficits. The goal must be to provide them with some type of information they can still make use of, so that these people and patients become again more self-reliant when making their ways through the building. Even if we fail to improve their spatial abilities, there is still the chance to elicit positive emotions with certain odors, which might in turn at least increase their experienced well-being while living in a nursing home.

Biophilic design and psychology share major goals: healthy people—satisfied and productive—in a healthy and clean environment. While clinical psychologists and psychiatrists are often confronted with mentally ill people, psychologists from work and organizational psychology try to optimize work conditions and life satisfaction for ordinary people within our society. Now, this is exactly what biophilic design is about: optimizing our environment so that it matches our abilities and needs in order to become happy and stay healthy (e.g., Gray & Birrell, 2014). Gray and Birrell, for example, ran a longitudinal study concerning biophilic design, e.g., natural lighting, ventilation, and significant plants in an office building. Their preliminary data revealed higher productivity, well-being, and work satisfaction, while stress was reduced. Other researchers, for example, developed a so-called Biophilic Design Matrix (BDM) as an aid for designers to identify and quantify biophilic features (McGee, & Marshall-Baker, 2015). The Authors demonstrated that this matrix can successfully be applied within a pediatric healthcare context. Thus, it might be possible to "measure" the influence of the surroundings for patient recreation and maybe also for concepts like well-being. This matrix is, however, only a visual inventory of interior spaces. Therefore, we may again see that also within this domain of biophilic design, there is a bias towards visual features and visual appearances. What we need, in biophilic design *and* psychology, are more multimodal approaches integrating our senses. This approach lives up to the demands of our very reality. The critical endeavor will be to design our urban surroundings—including hospitals and nursing homes, office buildings and manufacturing facilities, schools and recreation sites, etc.—in a way that they activate all our senses. Additionally, our psychological approach might also be useful with respect to the concepts of *urban gardening* and *urban agriculture* (e.g., Cockrall-King, 2012), which almost automatically introduce new odors to the appearance of a city. Thus, many different applications in (urban) design and architecture are conceivable.

If we take all the above as a basis for biophilic design and architecture, it should by now be clear what this implies: we have a chance to design and change our environment in a sense that it matches a) our perceptual and cognitive abilities, b) our society's, and c) our own needs. We think that this interdisciplinary research project can provide valuable insights from human psychology for biophilic design and architecture.

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Relationship between Urban Morphology and Patio Housing in Mediterranean European Cities during the XV–XVI Centuries

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ABSTRACT

Through a brief analysis of the millennial use of the typological model of the patio house, the relations existing in the Mediterranean Europe between this model and the urban form during the 15^{th}–16^{th} centuries are exposed. The investigation is based on the documentary analysis and the construction phases of more than twenty traditional houses in the historic center of Granada, in the context of the newly fallen Nasrid city in the hands of the Castile Lords. It allows to appreciate the footprint of Islamic urbanism of Eastern origin in late medieval Europe, also existing in other geographical areas at that time, despite the different cultural roots, and partly still present today. This research is linked to the numerous contemporary studies that have been focusing on traditional architecture, trying also to provide a kind of reading of the constitutive processes of the medina of the Islamic West.

Keywords: traditional housing; Islamic urbanism; urban morphology; patio houses

INTRODUCTION

Twentieth century research on historical landscape and traditional architecture (Garcia Mercadal, 1981, p. XVI; Esquieu and Pesez, 1998; Marconi, 2004, pp. 491–520; Bulgarelli & Mazzeri, 2008. pp. 315–324) has tried to provide a reading of the main characteristic elements of the factory buildings in several European historic centers (moreover in Italy, France and Spain). The present work relies on such a strong renewed interest in historic buildings and pre-modern towns, yet it focuses more specifically on the patio house type. Such a type utilizes small courtyards and is an almost constant constitutive element of the Islamic medina and of the urban layout defined by the building codes used in the cities and rural settlements of the Byzantine dominions. This typological element is here analyzed in relation to its influence on the late medieval urbanism of the Mediterranean Europe.

In order to formulate a morphological reading of the traditional patio houses, which are preserved in several historic centers in the Mediterranean region, revealing their direct relation to the urban form that its adoption contributed to determine, one must previously address a general analysis of their original constituent features.

This type of study is based on the knowledge of the local constructive tradition, which is conditioned by permanent—due to geography—and impermanent—such as culture and social structure—factors.

It is also fundamental to delineate the spatial constituent elements, as well as the different types of existing houses in different territorial areas depending on the region and its climatic conditions and the social class of origin of their promoters. Therefore, the present study aims to focus on those elements that combine different urban medieval centers under the criteria of similarity, in order to be able to view the main changes introduced during the Modern Age.

It is important to include these assessments in order to appreciate what was built in Southern Europe throughout the Medieval Era. The analysis of the urban environment along with its landscape is universally recognized by the Authors who treat these issues as one of the key points to understand the diachronic evolution of the traditional domestic architecture before the great urban changes introduced under the modern monarchies of the Old Regime, in order to preserve it (Hakim, 2004; Fiengo & Guerriero, 2008; Formenti, 1933; Giovanetti, 1997).

The present work also analyzes an important number of houses of medieval origin still almost completely conserved in the city of Granada, Spain, after a long and detailed research *in situ* (Pica, 2016). The analysis of the location of each house in relation to its surroundings shows how these dwellings have been transformed into complexes of manorial housing. Built over preexisting properties, acquired by Christian nobles throughout the 16th century, the actual mansions unified different medieval housing units.

An archaeological and documentary reading of a part of the domestic architecture of the 15th and 16th centuries in the historical center of Granada is proposed, integrating it with a comparative analysis of other data documented in previous times (since the Middle Ages) on other territories bordered by the *Mare Nostrum*. At the same time, we will mention some analogies and differences with contemporary historical buildings, that is to say, late medieval, studied in the historical towns of Siyasa (Cieza), Murcia, and Toledo. This type of analysis conveys to identify the clear correspondence between patio housing types and the organic, compact morphology of the Islamic city, as well as of the pre-modern Mediterranean towns of byzantine foundation, built under similar urban codes. The study includes different aspects, such as socio-economic, anthropological and geographical, as today the interdisciplinary methodology offers a great contribution to the diachronic studies on the traditional domestic architecture sited in the urban and rural geography of the Mediterranean.

THE PATIO HOUSE FROM ANTIQUITY TO THE MIDDLE AGES: ORIGINAL URBAN LAYOUT, MORPHOGENESIS, AND EVOLUTIONS

Basing the analysis on a brief tour through the millennial use of the typological model of the patio house in some of the main cities of Mediterranean Europe (Picone, 2009, pp. 88-92; Vitruvius, 2006), without forgetting certain references to the northern coasts of Africa (Fentress, 2000, p. 23; Missoum, 2000, p. 247), some specific morphological elements are briefly described. This allows us to observe the relations between the patio house type and the urban form throughout the High Middle Ages until the 15^{th}–16^{th} centuries in these territories.

The courtyard house is a constructive archetype rooted in the urban agglomerations of the Indus (Mohenjo-Daro, 3000–2000 B.C.), Tigris and Euphrates (Sumeria and Ur, 2175–2000 B.C.) and Mediterranean (Mycenae, 1550–1100 B.C.). Its regular layout ensured defense and hydraulic supply and included private patios (Orihuela Uzal, 2007, p. 229). These urban centers are based on the aggregation of domestic buildings with patios through the juxtaposition of two or more median walls (the lateral ones and the background) to the other houses (Pica & Garcia-Pulido, 2014, p. 54).

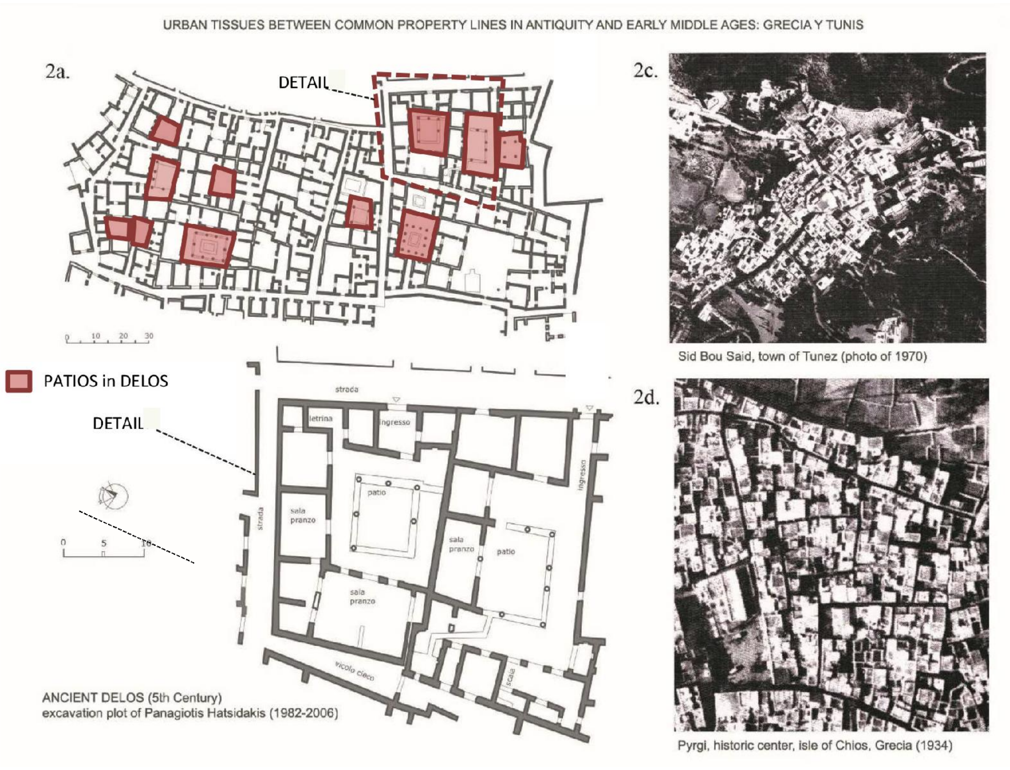

Figure 1. Study on settlements of the Mediterranean South-East: Greece and Tunisia. V. Pica, 2014.

It should be noted that N–S was the preferential orientation, a fact that continued to occur throughout the Middle Ages in both the Byzantine cities of the Eastern Mediterranean and the Islamic ones of the West. Many documents of the Antiquity indicate this orientation of the house with patio as the best predisposition towards solar light. Therefore, it will come to be fixed like a constitutive norm of the good building practice during the Roman time and beyond (Perlin & Butti, 2006, p. 92; Moretti, 2005, p. 71; Vitruvius, 2006, book VI, chapter VI) (Figure 1).

The basic concept in this type of housing is enclosure of the diverse domestic spaces. In the Greek house these are included in factory buildings juxtaposed around an open space—Greek *kortós*, Latin *cohors*, Italian *corte*—(Rispoli, 2014, p. 35) that was sometimes placed in central position and in other contexts on one side of the plot (Hakim, 2012, p. 140). This last provision of the lateral court is frequent in the traditional domestic architecture of central and northern Italy, where the Hellenic component was very strong in antiquity (Guidoni, 1981, pp. 3–53; Caniggia, 1984).

The house with central courtyard in the urbanism of Islam and Byzantium: Relation with the medieval Euro-Mediterranean city

The study of the stratified pre-modern historical Mediterranean city, having an apparently “spontaneous” development, starts from the understanding of the constitution and the evolutionary processes undergone from its foundational nucleus, as well as from the analysis of the environmental determinants, followed by certain patterns and codes common to many cities in this region (Moretti & Bori, 2005, p. 71).

The urban layout is often determined by the use of the patio house type, and has consequently a compact organic structure, as it has been observed by many architects and researchers in recent times.

This dense urban tissue is present in many traditional cities across the Mediterranean Europe (Petruccioli, 2007, pp. 38–45).

Recent researches have revealed common aspects or similar identifying features between Byzantine and Islamic urbanism, which have been developed since the early Middle Ages. These studies offer a scientific basis for the comparative analysis between some cities and towns in southern and central Italy undergone under the Byzantine domination, and others located in different Euro-Mediterranean countries (Hakim, 2008, p. 40). Some of the Italian territories were also, although for a brief period, under the Muslims (most of all in Sicily during the 9th–10th centuries) (Guidoni, 1979, pp. 575–597). Therefore, they can be more directly compared with other European urban centers of Islamic foundation, such as those of the Iberian Peninsula (Navarro Palazón, Giménez Castillo and Garrido Carretero, 2014, pp. 337–384).

The land parcel network of these urban centers is characterized by an extensive presence of dwellings among patio houses. These have been built after a series of customary practices, present both in the Byzantine law and in the jurisprudence of Islam, oriented to the management of the urban space and the intervention on it, which took into account the neighborhood relations.

The existence of adjoining walls between several residences with a courtyard, which is due to the type of housing adopted, and present especially in densely built cities, together with the narrowness of the streets, forced the respect of these norms (Hakim, 2013, p. 98).

In order to understand the development of the courtyard types in pre-modern Europe and its connection with the Islamic West, one has to consider how Arabs, originally nomadic people, have established their settlements since ancient times. As Islam spread rapidly from Arabia in the 7th century, Muslims began settling in conquered towns, and with time adjusted their morphology to suit the requirements of the Islamic lifestyle. Numerous towns and villages were also created across the vast territory of the Muslim world. Islam have always encouraged settlements based on the nurturing of a cohesive community within physical setting mostly consisting of the erection of the mosque, the necessary community facilities, and housing. It is also necessary to understand how some old constant mechanisms, such as the processes of formation and organization of the space around the central courtyard, is linked to certain environmental and functional constraints proceeding from pre-classic antiquity customs (Golany, 1995, pp. 72–73).

These norms had influenced the Mediterranean and Eastern settlements until the Middle Ages. Dwellings were usually built in small segments and increments across a long span of time. The nature of the process, coupled with predominant use of a clustered morphological system, meant that the relationships of adjoining neighbors in matters related to building design decisions generated conflicts. The early Muslim jurists tried to resolve such conflicts within the framework of *fīqh*, the science of Islamic Jurisprudence, which mostly rooted in Medina, Arabia, during the first decade of the Hijry era (622–632 A.D.) and in the Sunni Maliki Schools of Law, which is attributed to Imam Malik (8th century). According to this analysis, it is possible to observe that the medina of the medieval Islamic West responds directly to millenary criteria, according to designs based on constant identifying features, which are also present in many of the historical cities of pre-modern Mediterranean Europe. These criteria have been developed within the building standards and the urban codes of both Islamic and Byzantine dominions, being spread throughout the Italian territory of the Exarchate whose seat was in Ravenna between the 6th and the 8th century.

The quoted identifying features allow us to appreciate nowadays the still visible trace of Islamic and Byzantine urbanism of Eastern origin in several geographical areas in Europe, despite their different cultural and historical past.

According to the previous assumptions as well as to recent Spanish researches, the schemes of aggregation that determined the formation of the urban layout of the medieval Andalusian and Maghrebi medina are not casual, but rather correspond to certain rules maintained throughout the Middle Ages (García Bellido, 2000, pp. 243–284; Navarro Palazón & Jiménez Castillo, 2008, pp. 259–298). This also reveals the Islamic footprint on the urban and rural construction of Sicily throughout the same period, as evidenced by recent archaeological findings (Molinari, 2000, pp. 177–197), as well as the morphology and the toponyms of Sicilian cities (Casamento, Di Francesca, Guidoni, Milazzo, 1984).

Specific building standards prescriptions were established both in the Quran and the Tradition (Hakim, 1986, pp. 12–13), as it has been introduced before, and in the Byzantine urban law, which was generated in the Middle East from the beginning of the 6th century. The Islamic ones were maintained throughout the Middle Ages in all the conquered territories, while the Byzantine are less visible in Italy (only in some rural hamlets in the middle and southern parts of the peninsula) and in other Euro-Mediterranean regions, due to various historical upheavals. Some of these prescriptions imposed that: the height and views of the terraces were limited, as from there the neighboring patio had not to be seen; one's door could not open in front of the other's door; the windows and openings to the street were suppressed or reduced. The Byzantine Treaty by Julian of Ascalon (533

A.D.) prescribed similar rules and recognized the antiquity of some of these practices that would proceed from Palestine. This treaty was the first normative apparatus of urban planning regulation in the Middle East, whose contents were collected in Medina by Imam Mālik, 712–795, and were broadcasted by the Mālikī legal school in Egypt during the Abbasid caliphate in the treatise of Ibn Abd Al Hakam in Fustat (767–829), lost. Documents have also been found on Syros Island in the Aegean Sea, dated about 1200 B.C., describing similar customs (Hakim, 2008, p. 28). Muslim jurists such as Ibn al-Imam have left sentences relating to issues concerning the parcel and respect areas of each dwelling when two or three walls joined (Ibidem).

At this point, a difference can be detected. While the Roman and Hellenistic traditional house type (to which the most common traditional Arab-Islamic housing must be ascribed) maintains a scheme with direct access from the street through straight lobbies in line with the axis of symmetry (Roman atrium), Muslim housing developed architectural solutions linked to domestic privacy. The bent entrances (in Spanish Arabic *zaguanes*) were adopted as a more usual solution to get access to the houses, and were preferentially opened to the *darb* (plural, *durb*, *adarves* in Spanish Arabic, *darbi* in Sicilian) or the secondary narrow *cul-de-sac* street, used as a filter from pollution, noise etc. before reaching the main streets. Although it was not the only reason, the expansion of the described domestic typology caused the diffusion of the main identifying features such as the *adarves*, the disinterest for the façades and the agglomeration of houses inside large districts, leaving the stores to be along the main streets forming the traditional souks (pl. *aswāq*, in Arabic) along many of the public streets. This is one of the main constitutive element of what is being called by recent research focusing on the Islamic city, the organic system of the compact city "*cluster*", which was based mainly on the juxtaposition of median walls.

The Islamic law also provided for each neighbor to respect the community and help maintaining the "*finā*" (outdoor unbuilt space surrounding the house that is considered to be part of the same property) of the neighborhood, religious buildings, gates, walls, cisterns, ditches, moats, and cemeteries. According to the *fiqh* of *mālikī* tradition, the space of tall plants or "air" could be sold for building, sometimes used for commercial or artisanal use (in this way projecting volumes, called *saledizos* in Spain, were generated on the street of warehouses and houses for rent). Likewise, residential additions over the streets, called *sabat*, as well as irregular insertions of domestic spaces of one's property into another, called *engalabernos* in Medieval Spanish, were allowed within the *finā*. The *engalabernos* are occupations of neighboring land parcels by the acquisition of the right to build on their air, or by acquiring part of the neighborhood property (Figure 2).

Roman law, which is the source of the jurisprudence of the so-called Western world, did not contemplate *finā*. Nevertheless, this concept has influenced the urban planning of almost every city of the Mediterranean during the High Middle Ages, remaining its footprint until the Modern Age in many of the territories bathed by this sea, especially in rural areas. This is because both Byzantine and Islamic civilization promoted from their outset local urban practices adaptable to specific cases and, in fact, local tradition was an important source of Islamic law in urban planning.

The compact urban plot and the houses with patio in the Iberian Peninsula

Traditional courtyard houses have survived in many rural areas and urban centers in Spain and the Middle East, but not in most Italian cities that fell under the rule of Byzantium or Islam during the Middle Ages (Guidoni, 1981, pp. 3–53). It is plausible that this event is due, among other factors to

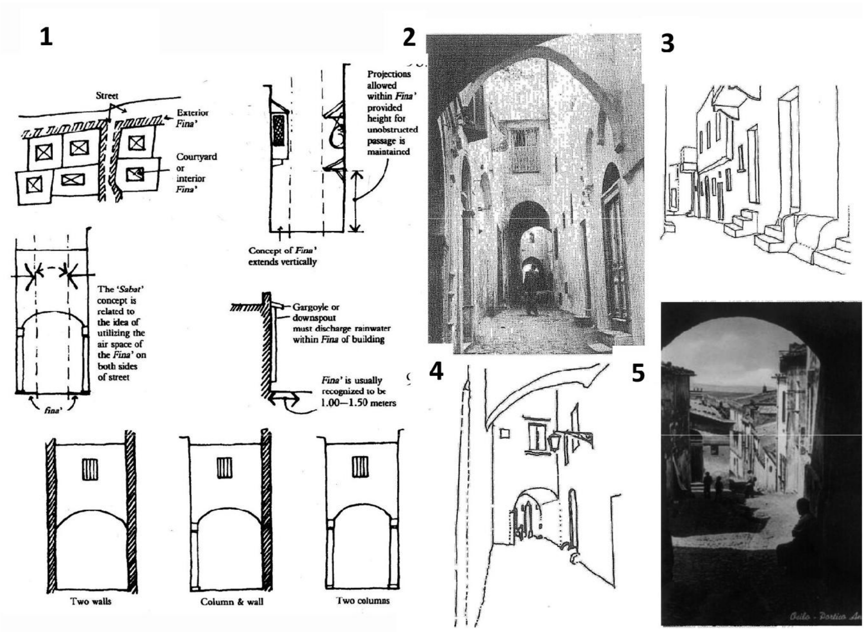

Fig. 2. (1) Sketches of B. S. Hakim on finā and sabat, examples in the Mediterranean. (2) Sabat in Tunis (1970); (3) Amorgos, Greece (2001)[6]*; (4) Ostuni, Puglia, Italy (1979); (5) Medieval Osilo, passageway under a sabat (Sardinia), historical photograph*[7].

Figure 2. (1) Sketches of *finā* and *sabat* by B. S. Hakim. (2) *Sabat* in Tunis (1970); (3) Amorgos, Greece (2001), after (Hakim, 2008, pp. 27, 30); (4) Ostuni, Puglia, Italy (1979); (5) Medieval Osilo, Sardinia, Italy, passageway under a *sabat*, after (Hortu & Sanna, 2009, p. 126).

the inheritance of the Islamic culture in Spain that lasted until the 16th century and still exists in some Eastern Mediterranean regions. In the case of the historical centers of Granada and Toledo, exemplary manorial types from the late 15th and 16th centuries are preserved, although with several changes, having been maintained throughout the Modern Age (Pica, 2013; Passini, 2004).

Soon after the arrival of the new Christian residents in Granada in 1492, there was not a complete cancellation of their traces, as evidenced by the survival of some Andalusian customs related to housing: this is the case of the ditches, the city walls, and the pleasant patios of the houses (Barrios Rozúa, 1998; 2006) (Figure 3).

The historical value of these Spanish urban centers and particularly the historic center of Granada, is very relevant, as much for its singularity as for its relation with its environmental surroundings (Molina Fajardo, 2012) as well as with other European regions bathed by *Mare Nostrum* because of commercial interchanges. Furthermore, this town exhibits the last architectural elements of the types of houses with patio in Spain, which possibly conditioned the urban layout of many medinas of *al-Andalus* founded during the Middle Ages.

Within the Mediterranean context, this Spanish historic center allows to appreciate the main morphological characteristics that may have existed in the traditional housing of Southern Europe between the 15th and the 16th centuries. For this reason Villanueva Rico refers that the inventory of the real estate donated under certain conditions to mosques, madrasas or other religious or public

Figure 3. North facade of the inner courtyard and sectors of the east and west navies of a house located in the Cuesta de las Arremangadas n. 6 (photograph by V. Pica, 2010).

Muslims institutions, called *habices*, *waqf*, or *habis* in the Maghreb, dating from 1527, reports the presence of several *cul de sac* streets. These are also present in other Andalusia cities (Navarro Palazón & Jimenez Castillo, 2008, pp. 266–267) and are,

> characteristics of the medieval Muslim cities where it is not necessary that the street leads to somewhere, since the street has not been drawn previously and along its sides the houses have been raising, as in medieval Christian towns… (Villanueva Rico, 1966, p. 7).

The same notation is given by (Garcia y Bellido, Torres Balbás, Cervera Vera, Chueca Goitia, & Bidagor Lasarte, 1954, pp. 21 and 79; Arizaga Bolumburu & Solórzano Telechea, 2010).

It is important to observe also how the traditional Islamic architecture perpetuated in the urban environment of Granada until the arrival of the Christians kept the ancient prescriptions on solar orientation and other features ruled by the *fīqh*, determining specific designs in plant and certain distributions of the factory blocks on the parcels (Figure 4).

In the urban environment generated by this legal framework, the street is not conceived for the passage of wheeled vehicles, and the use of the chariot should be excluded (Lézine, 1971: 29; Le Tourneau, 1957; Navarro Palazón & Jimenez Castillo, 2007:138). Eugen Wirth (1975) proposes that the features of *cul-de-sac* in these cities are rooted mainly by Mesopotamian principles. It is astonishing that such a millenary urban practice is still visible in Spain.

It is common to find several, well preserved medieval *engalabernos* in the quarter called *Albaicín*. The houses of our research offer three examples: one in the Benalúa Street nr. 11, first plant, another in the Cuesta de San Gregorio nr. 13, on the whole height of the house, on the NE side of the plot, and another on Calle San Juan de los Reyes (old flour mill) (Figure 5).

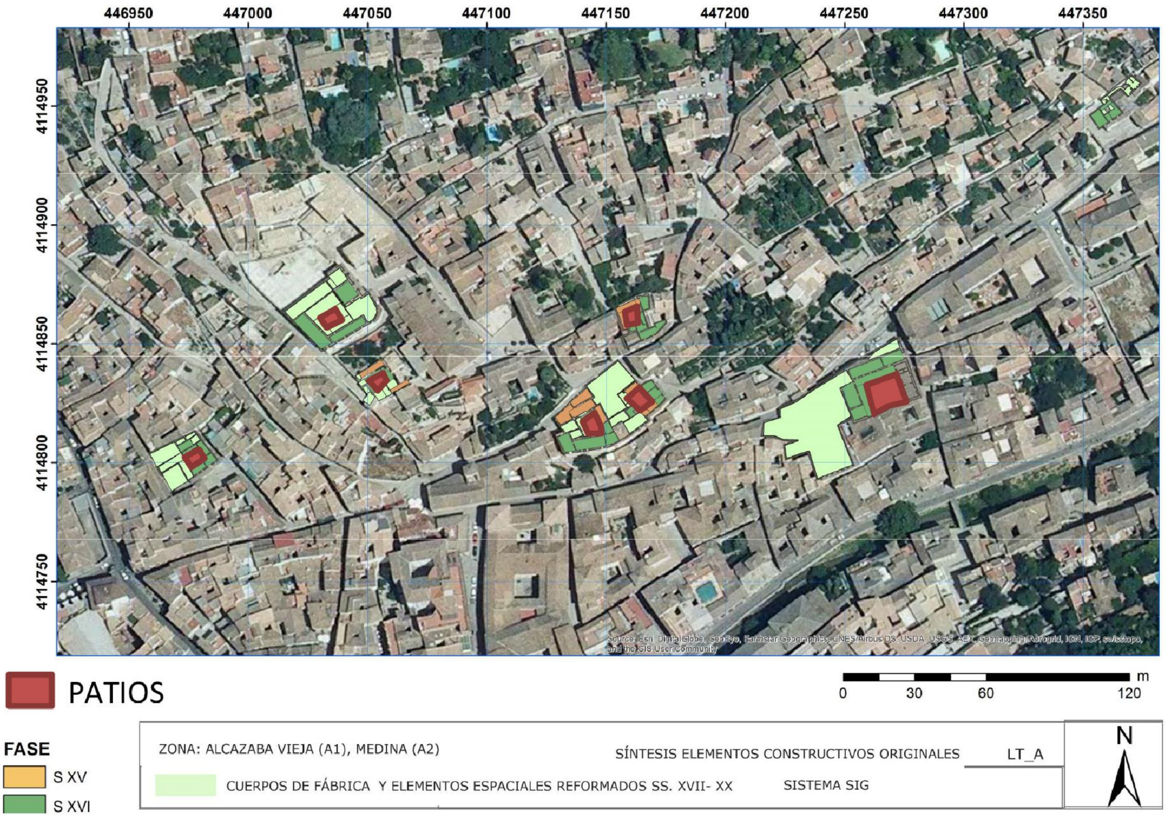

Figure 4. Houses of the 16th century with N-S oriented patio, Albaicín, Granada.

Figure 5. House in the Benalúa Street, n. 11, Albaicín, Granada (photograph by V. Pica, 2010).

The compact form of the city, with its *cul-de-sac* and the common use of the private patios can be directly related to bioclimatic efficiency standards observed by the Andalusian *alarifes* (foremen) as well as in ancient times (Pica, Garcia-Pulido, & Osuna Vargas, 2013).

Hassan Fathy (1986) has introduced climate among the main determinants of urban form, together with religion and historic background.

Water was of fundamental use in order to refresh spaces and for religious practice. In such an urban structure, water supply systems could be multiple, as in Murcia, where it was obtained not only through the network of the channels of ditches under the streets (like in Granada), but also from the water table by wells. Moreover, on the floor of the open air patio it was often located a rain-water tank, as in roman times. A relevant role in the process of supplying drinking water in private homes was performed by professional water givers or *azacanes* (Navarro Palazón & Jimenez Castillo, 1995, p. 402).

Another noticeable feature related to the medieval urban Andalusian environment is the presence of a few main road axes with commercial functions that articulate the medina putting in communication the main doors and uniting the center with the periphery.

For understanding the historical fabric that we have been analyzing, it is also important to make a distinction between the main object of this study, which is the actual housing realized by the urban oligarchy during the 16th century, and the Castilian medieval house in all its nuances and typological variants.

In order to notice these characteristics, the analysis of the documents is essential. One must especially focus on the *habices* of Granada, which are a valid reference for the study of the historical urban fabric of the city and the domestic architecture of lesser value than the nobiliary one. Thus, we can see how, at the end of the 15th century, although the separation of the commercial and residential function would still be widespread in most of the districts of the city, the realization of bivalent houses occurred gradually, with at the ground floor the workplace and at the upper levels the domestic spaces. Although not explicitly covered by our subject, it is important to take into account these bivalent houses in order to complete the description of the Andalusian medieval housing, present both in the closed commercial areas (*alcaicerías*) and along the open commercial axes. In these small domestic buildings, there were pieces with direct access to the street called *casa puerta*.

Finally, it is possible to distinguish two main types of houses, depending on the existence or not of the patio, which according to its size gets the name of "patinejo", "patio", "corralejo" or "corral". From the analysis of the mentioned *habices* it turns out that very few *corralas* (big courtyards) existed until 1527, being the city still densely built (Orihuela Uzal, 2015, p. 467). Stores were distributed both in urban spaces specifically meant for commerce (see the *Alcaicería* neighborhood) and on "commercial" streets. They belonged to separate architectural types, compared to houses with internal courtyard, and were similar to the compact block house type. Many of them could often count on a high floor "chamber" intended for housing use, but without a central patio. This typology was inserted in a regular framework, parallel to the streets and within narrow parcels. Warehouses as well fit the same block house type with no patio. These independent units were often used as commercial spaces and had their own direct access from the street (Figures 6 and 7).

The inventory of *habices* calls "palaces" the spaces designed for private rooms use of both Moorish and Christian housing. When referring to them indicating their position with respect to the patio, historic documents usually use the name of "aisles", or "naves" that is understood as the rectangular building blocks in which these rooms were inserted (there may be two adjoining rooms in one

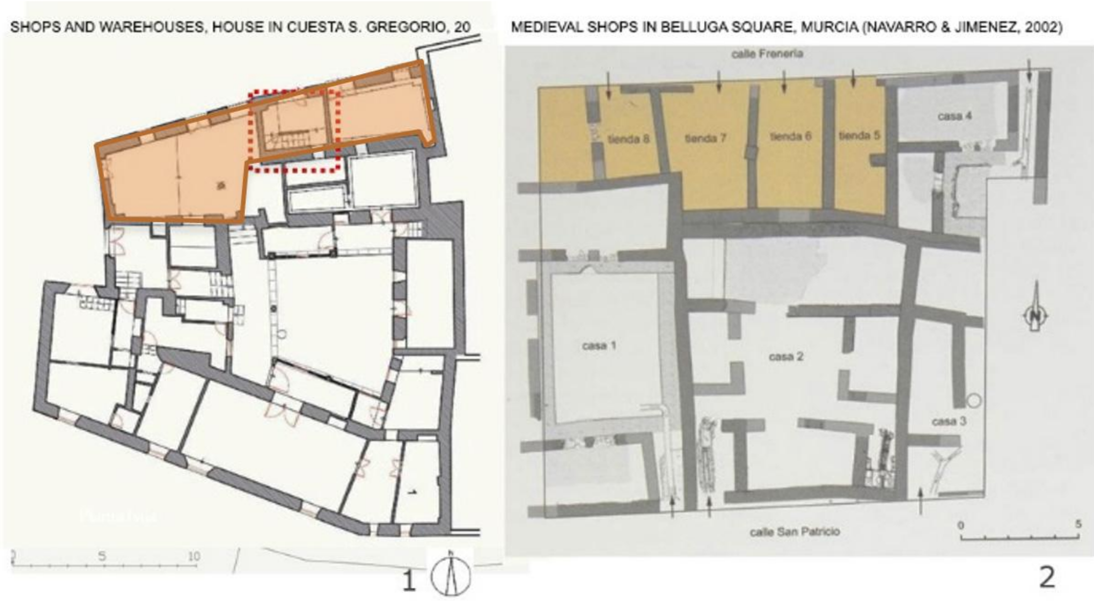

Figure 6. Shops onto the house in Cuesta de las Arremangadas 6 in the Albaicín, Granada. Comparison with others in Murcia.

Figure 7. Shops onto the house in Cuesta de las Arremangadas 6 in the Albaicín, Granada. Surveys and restitution of the original state.

single nave) and that were distributed around the central courtyard. Each of them had its own independent gable roof.

According to the 1527 *habices*, almost all the houses in Granada had a ground floor with a portal at the entrance and a variable number (from one to four, depending on the size of the plot) of naves or building blocks distributed on the sides of a patio inside.

It is important to observe the modifications suffered by the city of Granada from the end of the 16th century to modern times through subsequent reforms.

The majority of the houses of the Muslim period were reformed already in the 15th century, due to an increased need for space after the refugees following the advance of the Christian *Reconquista* front and the consequent more intensive use of housing and greater densification of the city. Given the impossibility, in most cases, of expanding the plots, plants were added and heights raised (Almagro Gorbea, Orihuela Uzal, & Sánchez, 1992, p. 141) (Figure 8).

Figure 8. Diachronic evolution of the house in Cuesta de las Arremangadas 6, Albaicín.

The transformations undergone by medieval housing in the last decades of the Nasrid kingdom were preserved in the Moorish dwellings, which still represent the last chapter of the Islamic construction stage in Granada, although quite varied through Castilian influence.

It was at this time, between the end of the 15th century and the beginning of the 16th, that the more comfortable houses started extending the use of galleries connecting high plants in several sides of the patio, in order to facilitate the access to the upper rooms (Orihuela Uzal, 2002).

The Muslim house with an interior courtyard had thus come to resemble the type built in the Christian kingdoms. Therefore, it was not a problem for the new Christian urban oligarchy, at least in the first period, to adapt the preexisting medieval housing to their domestic uses. Moreover, the notables of Castile admired the luxury of certain Islamic nobility houses, so the new residents sometimes did not demolish them (Arié, 1982, pp. 279 and 329) (Figure 9). As Villanueva Rico puts it, "Immediately after the conquest, even a Renaissance spirit like the Navagiero, accustomed to the refinements of the Italian cities, is astounded by the beauty of this Andalusian city..." (Villanueva Rico, 1966, p. 1).

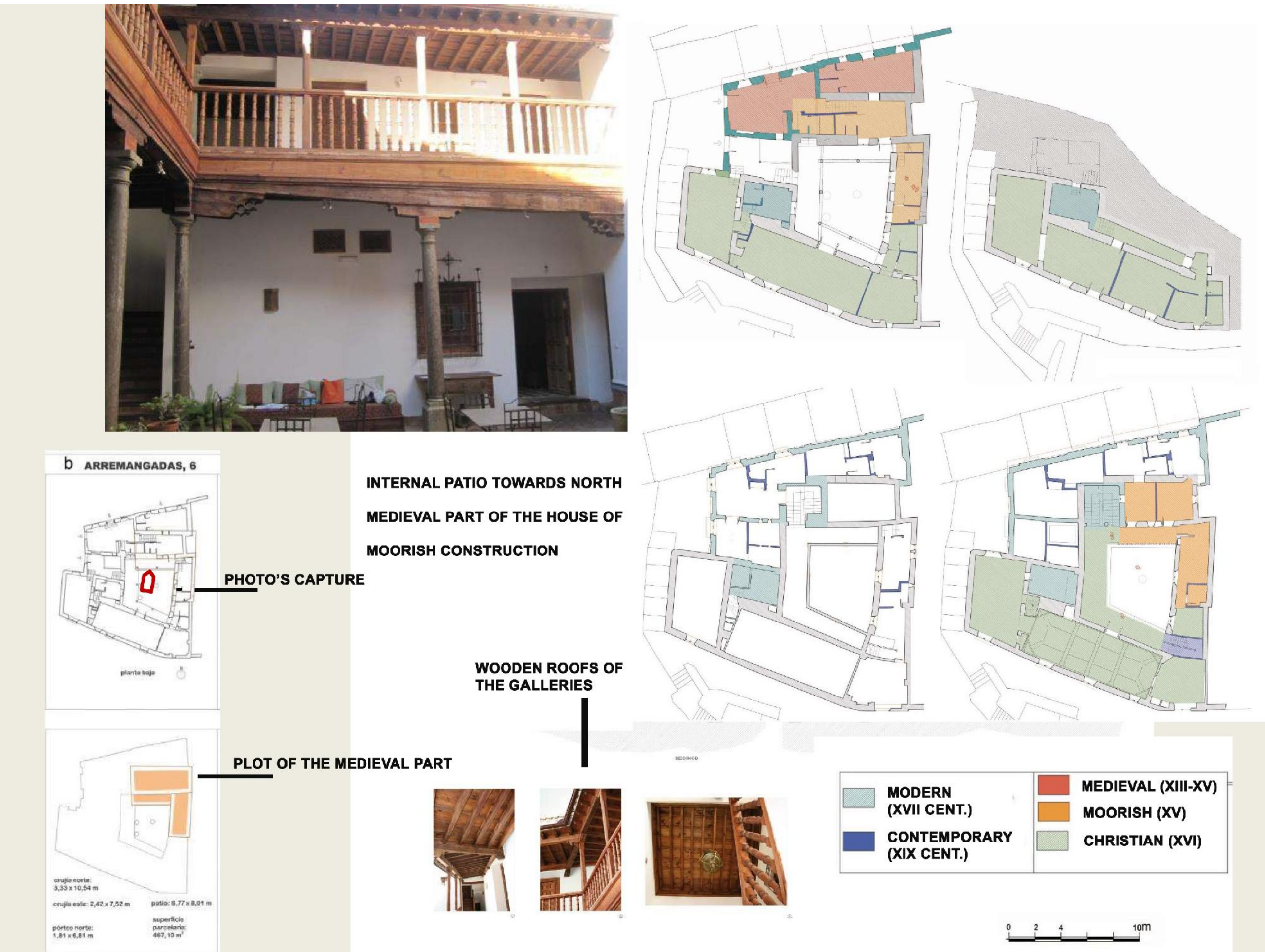

Figure 9. Diachronic evolution of the house in Cuesta de las Arremangadas 6, Albaicín.

The royal decrees on urban planning issued by the centralist Catholic Monarchs after the conquest of Granada, though, clearly imposed an abrupt design change, searching for their own cultural identity against the traditional urbanism that had developed throughout the Middle Ages (Vincent, 1993, pp. 307–319; García Granados, 2000, pp. 97–134). As Gallego Burín noted, although the Islamic urban structure was preserved almost completely, new architectural efforts were undertaken in the city as well as the demolition of several buildings, both under the Catholic Kings, who undertook defensive, sanitary and monumental works with a clear political and aesthetic sense, and successively, under the Emperor Charles V (Bosque Maurel, 1988; Juste, 1995). Since the first period, the historical labyrinth of fabrics underwent transformations: streets were widened and *sabats* where demolished, according to the royal ordinances (Barrios Rozúa, 1998; 2006).

CONCLUSION

Recent researches on the relation between urban layout of historic centers and the use of Mediterranean patio houses since ancient times allowed to analyze comprehensively the factors and the urban codes which contributed to determine this linkage. Codes spread by the Byzantine and Islamic civilizations throughout the Near East and the Mediterranean territories that were under their direct or indirect rule and/or influence.

Understanding these characteristics as well as the urban environment of most of the Mediterranean Europe during the 15th and the 16th centuries is especially possible through the study of the historic centers of Granada and other Spanish cities where, unlike other European cities, the medieval urban tissue built before the capitulations has been partially preserved. Their analysis entails understanding the genesis and development of the Islamic medina. Cross-sectional readings are involved here for the various disciplines required by this type of scientific work and the different edificatory types. In fact, the main cities of *al-Andalus* have been the subject of study (including excavations) of many Authors.

It has been largely documented how Christian royalty began to give to 16th century Spain the planning rules and architectural ideas that were destructive to both Islamic and Byzantine urban practices, a process similar to what occurred during the following centuries to the rest of Europe.

Nonetheless, in Spain especially the quarter of the *Albaicín* of Granada still maintains a few medieval houses, which allow to appreciate traditional dwellings and their evolution throughout the analyzed period, as well as their relation with past traditions, rooted in ancient times.

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The Promise and the Limits of Biophilic Architecture

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ABSTRACT

Biophilic design promises the healthy effects of nature amidst human artifice. It has proven human benefits but advantages for the health of natural systems are moot. Images of natural forms can evoke biophilic responses using little more than paint and imagination. Analogous effects can be achieved with electronic screens and virtual reality but living systems pay the price. High-rise buildings with façades covered by a "forest" of trees are powerfully biophilic but the tons of concrete and steel and constant input of pesticides, fertilizer and servicing energy they require has a net negative impact on nature. Drawing partly on recent research undertaken with Deakin University, this essay proposes that if biophilia is about human health and biourbanism is about urban life in all its form, then a core concern with the biocentric needs of urban non-humans must inform the otherwise anthropocentric agenda of architects and designers.

Keywords: biocentricity, biophilia, biophilic design, design guidelines for non-human species, fractal geometry, green roofs, illusions of nature, Modernism, natural systems, vertical forest, virtual reality

INTRODUCTION

Biophilia is "the inherent human inclination to affiliate with nature" and has proven benefits for human well-being. Biophilic design is "about creating good habitat for people as a biological organism in the built environment". Biophilic design promises the healthy effects of nature amidst human artifice, its techniques are increasingly well documented, and it is beginning to establish its own orthodoxy, e.g., through the "14 Patterns" promoted by Browning et al. (2014). There are dangers in any orthodoxy, and the architectural profession has a propensity to adopt new ideas with an enthusiasm that obscures, in a mist of aesthetic excitement, more subtle concerns about the social and ecological function of buildings and space. Biophilia and biophilic design appear to be falling into that category. There is potential for biophilia to inform practice within a responsive ecological design framework. However, the excitement surrounding the discovery of biophilia by the architectural mainstream is often expressed in images that represent little more that the dressing up of modernist forms under cloaks of living greenery—greenery that may or may not survive the vicissitudes of being located on windswept concrete planting platforms high above the ground.

The biophilia hypothesis promises the prospect of an approach to architecture and design that enhances human well-being at the same time as it celebrates and embraces nature, but it also holds the danger of being trivialized and appropriated as a new kind of greenwash. In addition, I contend, it can mislead its own practitioners by convincing them that they are being "ecological" when, in fact, they are doing little more than applying a new kind of decorative layer to their structures. One goal of this paper is to draw attention to some of the potential contradictions of biophilic practice so that people can better manage and understand its use.

ALIENATION

In terms of the "bigger picture", even as nature is introduced in one form or another to the immediate human environment the resulting effect may be superficial as the deeper separation from nature created by the artificial environment remains ubiquitous. That separation, as Kellert and Calabrese observe, "is reflected in modern agriculture, manufacturing, education, healthcare, urban development, and architecture" (2015, p. 5). Alienation is intrinsic to the modern experience.

The antithesis of alienation is connectivity, which is in the essence of any relationship whether it is between humans or other denizens of an ecosystem. Humans are pattern-seekers, we have evolved to respond viscerally to nature and constantly look for connections, unconsciously and consciously. As evidenced by studies of our predilection for the patterns of fractal forms it would seem to be part of our biophilic hard-wiring. Regardless of the kind of acculturation driven by the technological fetishism of modernism, our pattern-seeking favors biophilia.

At the same time, there is an element of acculturation in biophilia. It may depend on repeated experience and need "to be nurtured and developed to become functional" (Kellert & Calabrese, 2015). For this reason, with the relative shortage of biophilic experiences in many modern cities, it may be all the more essential to create urban environments that ensure repeated experiences of biophilic input. Apart from obvious propositions, such as requiring parks and green spaces to be readily available and located close to the homes of urban dwellers (Beatley, 2010), one can imagine urban design strategies that place biophilic experiences in the course of everyday experience as a matter of routine, along people's routes to work, school, play, and entertainment. "The passages that are likely to work best are the ones along which people walk or cycle—travelling slowly enough to appreciate their surroundings, episodic experiences like bus and train stops might offer the canvasses for multiple biophilic techniques that, repeated on a daily basis, might nurture biophilic awareness." (Downton, 2016). Travelling by car in rapid traffic, always having to pay attention to potential hazards and other road users, offers much less potential for encouraging biophilia. This is a clear instance of where biophilic design strategies fit well with the ecocity design ethos prioritizing pedestrian and public transport. To be effective other than as a respite from the rest of the city, biophilic architecture has to be integral to the whole urban fabric, including, and perhaps especially, in major public places, and certainly in the case of railway and metro stations and other key public transport buildings that thousands of people experience on a daily or weekly basis.

ILLUSIONS

Illusions of nature can promote biophilic psycho-physiological responses in humans. Strong biophilic responses can be triggered through indirect experiences of nature, including 2-dimensional artistic representations of nature on canvas, paper, screens, etc. (Taylor, 2006; Joye, 2011; Salingaros, 2012). Arguably, although related to human sensory systems, "virtual" evocations of nature are not reality. It has to be acknowledged, however, that biophilic effects are measurable in some un-natural environments, like hospital rooms, when people are exposed to images of nature or illusions of nature, such as artificial sky. The manufacturers of "virtual skies" claim, with some justification, that the effects of their technology include "increased relaxation and psycho-physiological restoration" as a "direct result of enhanced biophilic engagement"—and this despite the fact that the virtual clouds do not move (http://www.skyfactory.com/products/luminous/personal-revelation/). Nature is never in stasis so, how long can the illusion of nature be maintained without movement? If authenticity matters, when does lack of authenticity become a problem, or can human senses and consciousness be so easily tricked that it does not, in effect, really matter? After all, some people enjoy wearing virtual reality goggles (which images owe a great deal to the understanding of fractal geometries for their realistic effects).

It is well established that measurable biophilic responses can be evoked in humans by using images that are not alive. Research has demonstrated that images of branching patterns that obey rules of fractal geometry can trigger similar responses to those summoned by images of natural vegetation. Humans respond to the evocative power of art and the human affinity for nature is such that images of natural forms can evoke biophilic responses using little more than paint and imagination. The power of modern technology can amplify the disconnection between this curious ability to be emotionally moved by nature without its actual presence—analogous effects can be achieved with electronic screens and virtual reality.

In the case of advanced technology, whilst the biophilic effect may be similar, the impact on living systems is quite different. When you take into account the energy use and resource extraction needed to create and maintain the machines, satellites, cables, transistors, pixel generators, marketing, distribution systems, software engineers and general paraphernalia of global industrial civilization, the amount of impact on the natural world caused in the process of projecting electronic images is not trivial.

Illusory systems have a role to play. They are useful in environments that cannot easily accommodate real biological systems, such as MRI rooms buried inside multi-storey, deep-plan buildings. One can speculate that one day their capacity to operate in a manner divorced from reliance on functional biological ecosystems might result in them being considered essential technologies for making the interior environments of interstellar spacecraft bearable for any human occupants—the concept alone reinforces the ecologically disconnected character of illusory biophilia.

Yet, such magical systems of illusion do not make a positive contribution to the biodiversity or the biological functioning of the urban ecosystem. In order to offer cheering pictures in stressful environments, "artificial skies" and similar products consume resources and energy and release greenhouse gases in their manufacture and operation and contribute directly to general ecological degradation and accelerated climate change. Although the result of such resource expensive expenditure may be a wholly convincing video, a picture of the sky is not the sky (Downton, 2016).

ON VERTICAL FORESTS AND OTHER CONCEITS

At the other, more "real" end of the spectrum, elements of living nature may be transposed into the human constructed environment to create biophilic effects. This may be as simple as placing potted plants in an office or living room, or setting landscaping in close proximity to internal spaces to provide a biophilic aspect to those spaces. Roof gardens and green walls are increasingly popular ways to integrate elements of the living world with the built environment. The extreme manifestation of this approach has evolved in recent years with the advent of high-rise buildings with façades covered by a "forest" of trees—the most influential project of this type being *Bosco Verticale* in Milan. High-rise buildings with façades covered by a "vertical forest" of trees are powerfully biophilic but the tons of concrete and steel and constant input of pesticides, fertilizer, and servicing energy they require has a net negative impact on nature. Even relatively modest green wall systems are likely to be disappointing in terms of their actual *ecological* value.

Planting creepers in the ground and encouraging them to grow up a building is a different proposition from investing the additional energy and materials demanded by the high material and servicing demands of proprietary green walls. A Master's research involving a detailed analysis of "green façade" systems was undertaken under the supervision of Prof. Brenda Vale in New Zealand. The study concluded that in each case the extra energy related to manufacturing the additional materials and physical support for the plants meant that the plants could not possibly offset the carbon emissions emitted in the manufacture of that system. Furthermore, the unnatural settings required pesticides and fertilizers to maintain the plants (Prof. Robert Vale, personal communication, 6 February 2017). As Professor Vale's husband and colleague reports it, "The only thing worth having was a creeper growing up the building with its roots in the ground," which, he notes approvingly, is a mediaeval solution.

Green roofs are a different proposition from green walls and should be characterized as such. Whereas it is generally possible to create green walls with the simple mediaeval technique of training in-ground creepers up adjacent building façades, a green roof has to support whole plants on largely horizontal surfaces that may be many meters above ground. Green roofs need servicing, but if the growing medium, or substrate, is viable and the plantings are suited to the climate and levels of exposure, then they have the potential to survive with relatively minimal maintenance.

Research I undertook recently with colleagues at Deakin University on behalf of the Melbourne Metro Rail Authority made it clear that biophilia has the capability of being deployed in almost any environment and, in so doing, help facilitate human well-being (Downton, Jones, Zeunert, & Roös, 2016). The research explored what possibilities there might be to use biophilic design techniques in the design of new metro stations currently being planned for the City of Melbourne, Australia. The schematic design of each proposed station was examined for its potential to support or accommodate biophilic design interventions.

The research indicated that the essentially subterranean nature of metro environments make it impractical for them to support growing nature by relying on natural light. Vegetation and living systems can be supported by artificial light, although the energy and resource cost might be significant. To a limited extent, living systems might survive under "piped" sunlight (for which the technology is constantly, albeit slowly, improving). The limited amount of daylight available in such environments can be seen in such examples as Dingpu Metro Station in Korea, and although the natural light adds to wellbeing, it is at a relatively low level and not able to support much in the way of vegetation. By far the easiest way to introduce biophilic experiences in environments so starved of natural light is by virtual and evocative means both electronic (screens and projects) and artistic (two and three-dimensional imagery). Although it might be possible to imagine any number of tactile interventions that do not require vision, like natural material textures on surfaces in public space that can be felt rather than seen, such as wooden handrails.

Biophilia is about human health. and biourbanism is about urban life in all its form, then a core concern with the biocentric needs of urban non-humans must inform the (often superficial) anthropocentric agenda of architects and designers.

Although biourbanism is not about aesthetic preferences, aesthetic preferences are relevant because it is about design. It is about design that works within a scaffold of ideas concerned about working with nature, with its energies and flows. Most of all it has to work, not just look pretty. It should do both. Biourbanism is about urban life in all its forms. Biophilia is essentially about maintaining, or enhancing, the health of the human organism, the maker of urban systems. Biophilic experiences as described by Beatley in *Biophilic Cities* (2010) can only take place in the presence of healthy living nature. Natural systems and non-humans have non-negotiable needs to support their continued healthy existence—plants require soil acidity to be within a narrow range that suits their particular type, for instance. Such biocentric needs must inform the agenda of architects, designers and planners whose concerns are otherwise almost exclusively anthropocentric and driven by the concern with human wellbeing. Biophilia can contribute directly to human wellbeing and social health but it can only contribute to ecosystem health if it informs the ethos and ethics of the human city-makers and residents to sustain a core concern with the biocentric needs of urban non-humans. Biophilia must inform the otherwise anthropocentric (and often superficial) agenda of architects and designers.

Biophilic architecture works well for people. Nature is more demanding.

Biophilic architecture has a terrific "feel good" factor. Fundamentally, that is what it is all about, making humans feel more relaxed, happy and productive, but it comes at a cost. That cost may be unsustainably high if it requires energy and resources (including water) that have to be drawn from nature beyond nature's capacity to replenish or replace them.

The source for energy used can be shifted from damaging fossil fuels to renewables, which would improve the chances of being able to continue delivering biophilic devices that have a high energy draw. Resources are more difficult to deal with, in that many resources are neither replaceable nor readily recyclable. A shift towards using resources that are renewable would help reduce material impacts; handrails, for instance, could be formed from timber from sustainably managed forests rather than made of stainless steel or aluminum (and such a substitution would also introduce a biophilic tactile experience).

An argument can be mounted that says because biophilic design enhances people's awareness of the living world that awareness can be translated into a better understanding of nature and thence improved stewardship of the natural environment—love the world a little more and you'll take more care of it. Unfortunately, this argument may not have as much strength as one might wish. There are any number of instances of where humans express love and admiration of the natural world just prior to sacrificing its beauty because of a perceived higher value trumping its natural value. One thinks of mountain top removal to extract coal, or clear-felling complex, mature forest ecosystems to obtain wood-chips. Many duck shooters doubtless love ducks. If there is a correlation between the love of nature and its conservation, it can sometimes be very weak and it has been demonstrated time and time again that its strength is severely diminished in the face of economic forces, conventional wisdom, and the often variable sets of values that people choose to embrace and falteringly apply.

ALLOWING THE WILD

Biophilia is defined as something that happens to people. Nature itself, regarded as something other than human (although we are not other than nature), does not respond to biophilia. People acting in a way to support natural processes and living systems may be encouraged by biophilia, but designing for biophilia may only peripherally be supportive of the health of such systems. That requires more focused attention.

Biourbanism is about urban life in all its forms, human and non-human. Humans can manipulate natural systems and make or break their prospects for future survival, but ultimately urban non-humans have needs of their own. Humans can study and learn to understand something of those needs and even model ecosystem behavior, but we are not able to completely understand what happens in natural systems or exactly what their needs might be because the operation of any ecosystem and the life of organisms has arisen through evolutionary processes. We can acknowledge the needs of those organisms best by enabling them to continue their evolution. Their biocentric needs may not always be something that humans can determine but the best available understanding of those needs must inform the otherwise anthropocentric agenda of architects and designers.

Translated into action, this means allowing the wild to flourish, whether or not it is regarded as aesthetically desirable. Biophilia and biophilic design can be misinterpreted as—or reduced to—an aesthetic preoccupation ("shallow biophilia"). A genuine love of nature has to translate to a need to act on its behalf, whether or not there are obvious trade-offs with human benefit ("deep biophilia"). Biophilic architecture needs to have more than human well-being as its focus.

Modernism has always celebrated the joys of kicking over the traces of the past and heralding the triumph of the new over the old. Anxious to prove its superiority, it conflates “new” with “freedom” and “progress” and, even now, confounds attempts to conserve the old by portraying it as reactionary. The preferred canvas of Modernism is a *tabula rasa*, a blank environment without definition or limits. Lost in this indeterminate “space” fetishized by Modernist architectural and planning training, the practice of architecture is restrained only by the bounds of a designer’s ego, which means it has practically no bounds at all. The facts of life and the natural limits of place are willfully ignored in order that “creativity” is not diminished; in *The Fountainhead*, Ayn Rand’s character Howard Roark portrayed the architect-as-uncompromising-hero in a way that reflected quite faithfully the logically absurd premises of Modernism and it has helped confirm an ethos for architectural practice that has not really disappeared. The strangely selfish view of the world that sees it all as little more than a playground for architects has not gone away. Even as the globe is threatened by human-induced accelerated climate change there is a kind of warped idealism arising that sees the inevitable damage to existing cities, towns and buildings as an opportunity to build “new” and “better” places, Pheonixes from the flames of a burning climate—just like the Modernists during and after World War II.

However, natural systems do not have the luxury of being able to ignore what designers choose to practice and try as we might, there is no way to maintain civilization outside of the constraints of the *actual* context of place.

For the last ten years or so, I have maintained that the creation of ecological cities requires the development of Design Guidelines for Non-Human Species (Downton, 2015). My proposition is that an urban fractal or neighborhood should for example be able to provide sufficient viable habitat that it can support at least one key indicator species of fauna and a majority of the species of birds indigenous to the place. The same logic of non-human orientation also applies to individual buildings. For the architecture of high-rise buildings to accommodate non-humans, they might include nesting sites for birds that prefer cliff-like habitats and there should be no reflective glazing on the façades. Such responses would have little positive biophilic effect—the benefits would be almost entirely to birds. That is not necessarily a bad thing and a core concern with the biocentric needs of urban non-humans must inform the (often superficial) anthropocentric agenda of architects and designers.

Goals for biophilic cities should be entirely congruent with those for a healthy biourbanism. As a minimum, a city environment should encourage awareness of non-human nature, demonstrate its connection with the life of its hinterland and supporting region, protect the living systems on which it depends and value non-humans for their intrinsic worth, granting legal rights to nature and imposing penalties on humans for any damage or harm to non-humans. Biophilic architecture has to perform within the same set of parameters. In an increasingly urban world, the scope of architecture should be understood within its urban frame.

Civilization favors static built environments, but it is still a changeable, malleable beast. The cultural mainstream eventually responds to changes that start at the fringes or on the leading edge of society. Its use of language eventually changes as the central concerns of society change. The humble “buttercup” and another four dozen words relating to nature and the countryside have been redacted from the *Oxford Junior Dictionary* in favor of computer terminology like “broadband”. Why? Because the dictionary’s editors decided that digital technology was more “relevant” to modern children than objects and organisms from the natural world. Yet just as the use of language changes with changing values, so a determination to attribute value to nature can change the language and, ultimately, change core values in the mainstream.

Exactly how nature is valued also makes a difference.

It is becoming increasingly popular to assess the worth of nature in terms of "ecosystem services" and to assign monetary values to those services. The logic of this approach in a mercantile society is understandable but flawed, because if our innate love for, attachment to, and need for nature is reduced to a financial equation to justify itself in the human constructed environments of our cities, it undermines any concept of intrinsic worth. Innate love fits with intrinsic value and has an unconditional dimension. One of the main purposes of architecture and design is to make places that please the human spirit, sensibility, and aesthetic sense; disagreement about what exactly constitutes beauty does not diminish the value of pursuing it—diversity of expression and response is part of the dialogue of culture.

CONCLUSION

Cities are consummate human constructions that exemplify the civilizations that create them and—understanding that civilization is human culture that builds static habitat and is not the same as those cultures which eschew monumentalism and are fundamentally nomadic—we have yet to see a civilization that places nature at its heart. The reasons given for having "more nature in cities" are invariably anthropocentric (see "nature-deficit disorder" or biophilia). These reasons are about improving the quality of life for people (or enhancing real estate values). Non-humans are generally absent in the arguments. I would argue that the reasons for promoting urban nature are more profound and are about human survival. Without healthy natural environments, we cannot survive, and cities can make or break the natural environment. Our reasons for valuing nature in cities needs to move beyond the "selfie" view that puts a bit of greenery in the frame of urban portraiture; it needs to move beyond the proposition that integrating nature in our cities is good for livability, resilience, sustainability, and human life generally. Although all these are true—we simply need to embrace the knowledge that nature has its own needs and those needs may or may not be of benefit to the human strands in the web of life. Architects and urban designers would do well to develop that understanding as a core value in their design strategies. This point of view tests the limits of biophilic architecture and design as it is not strictly dependent on biophilic sensibilities, but it is dependent on valuing nature for its intrinsic worth.

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Building a Conceptual Framework for Smarting an Existing City in Mauritius: The Case of Port Louis

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ABSTRACT

Sustainable urban transformation, promotion of green economy, and investment in better urban living facilities seem to lack a connecting nerve fiber within this digital era. Smart cities offer such a connecting framework that links technology, human capital, community infrastructure, and governance in a bid to promote sustainability and ensure viability of cities. Such a relatively novel approach to urban development offers promise of enhanced performance and increased productivity within a sustainable milieu. The capital city of Mauritius has a valid framework for becoming "smart". This study aims at proposing a conceptual framework for smarting the city of Port Louis, which is the main administrative center and harboring the only trade port of the island. The viability and sustainability of such an undertaking will be pondered upon. The findings of this study aim at paving the way for the main stakeholders in urban development towards ensuring sustainable urban transformation of Mauritius using a smart conceptual framework.

Keywords: sustainable, urban, smart cities, existing city, Port Louis

INTRODUCTION

The 21st century human being is principally an urban dweller as confirmed by the inexorable movement towards metropolitan areas in a quest for better living opportunities. It is predicted that within the next 35 years, 66% of world population will be living in cities. Such a situation will add up drastically to the actual 80% of total carbon dioxide emissions of urban origin, while wanting more inputs in terms of water, energy, and raw materials (Wu, 2010). There is a common cognizance globally towards promoting a culture of sustainable urban development, which will ensure sound economic growth without jeopardizing resources for future generations. The prime dimensions of focus towards sustainability have been predominantly aimed at i) social, ii) environmental, and iii) economic indicators of cities (Klang, Vikman, & Brattebø, 2003; Maclaren, 1996; Moussiopoulos, Achillas, Vlachokostas, Spyridi, & Nikolaou, 2010; Spangenberg, 2002). However, there seems to lack an apparent connecting nerve that allows all these dimensions to really boost the urban sustainability movement forward.

In this digitally connected era, Information and Communication Technologies (ICT) can offer such a bridging component in the urban sustainability mix that eventually paves the way for the concept of smart cities (Deakin & Allwinkle, 2007; Paskaleva, 2009). Guidelines have already been laid out for promoters to invest into creation of new smart cities from the ground up with various economic incentives coupled with a Smart City Certificate (SCC) for the developers (BOI, 2016). This concrete commitment towards promoting Mauritius as an ecologically friendly and technologically advanced smart nation has been further substantiated by the issue of the first Smart City Certificate to Omnicane Ltd. for its smart city project at Mon Trèsor, in the Southeast of the island. Despite this being a bold statement of commitment, there is no such course of action for smarting current cities such as Port Louis. Such a gap in literature and policy to tackle existing unsustainable cities and propose ways to smart them out has been vehemently brought forth by Kitchin (2014a).

The capital city of Mauritius hosts the only trade port of the island and is the main administrative center. Port Louis is infamously renowned for its traffic jams during peak hours and relatively lack of green spaces and pedestrian friendly areas (Guttee, 2015). Another issue that holds a central position of Smart Cities is efficient waste management (Zanella et al., 2014). However, Port Louis generates 6,308 tonnes of municipal solid waste monthly with the majority being of organic origin (Jhingut, 2016). This Author also highlights that there is no waste segregation at source and waste management through recycling, composting or anaerobic digests is inefficient. Zanella et al. (2014) postulate that through a smart city setup and in-depth use of ICT, waste management will be optimized resulting in significant savings and ecological advantages. Such profile of the capital city of Mauritius offers much room for promoting a smarting up of existing setups.

This paper therefore aims at proposing a framework for smarting the city of Port Louis based on models used in other cities but by trying to circumvent the one-size-fits-all policy. The dimensions identified in the framework will provide policy makers with groundworks to build upon.

BACKGROUND

The capital city of Mauritius, Port Louis

Located in the Northwesterly side of the island and bordered by the Indian Ocean and a mountain range, Port Louis is a bustling city of 119,706 inhabitants living in 46.7 km^2. This makes it the densest urban area of the island.

Moreover, the capital city hosts the only trade port of the island and is the main administrative center as seen by the prominent presence of ministerial buildings, businesses, and head banking offices. This explains the large number of commuters that travel towards Port Louis on a daily basis (Table 1).

District	No. Employed Commuter Population
Port Louis	66,798
Pamplemousses	21,227
Rivière du Rempart	9,939
Flacq	7,169
Grand-Port	7,928
Savanne	4,779
Plaines Wilhems	43,326
Moka	21,684
Black River	18,717

Table 1. Employed population, inflow and outflow of workers by district.
Census 2011 adapted from (Statistics Mauritius, n.d.) (Table sourced by the Author).

Such a large number of inbound travelers create a heavily congested area during peak hours that Fowdur & Rughooputh (2012) estimate at a cost of 0.1 billion USD per year, entailing 2.9 tons of net emitted carbon dioxide per capita. This drags Port Louis far away from sustainability concepts in terms of urban transportation. Moreover, it should be noted that Mauritius currently shows only a 20% energy self-sufficiency with oil still being the major energy source of the island (Koodaruth et al., 2017). With respect to water resources in Mauritius, Prayag (n.d.) stresses the need to implement recommendations from major water dimension studies to avoid shortages. This is backed by reports from the Central Water Authority of Mauritius, which highlight a 50.1% non-revenue water getting lost within the system. Another dimension of Port Louis that is of concern is municipal wastes. Solid wastes collected from Port Louis and its suburbs are transported to a nearby transfer station at an average quantity of 6,308 tons per month with the majority of the wastes being organic (Figure 1). Sixty percent of organic wastes represents a huge potential for composting, while 13% and 12.4% of paper and plastics hold the promise of potential recycling. If such aims are achieved, the waste generated that would actually go into landfills will be about 10–15% of the actual amount. Jhingut (2016) points out that only 7% of solid wastes are actually diverted for recycling and composting.

Beyond energy, water, and waste issues, there is an apparent inability for Port Louis to deal with heavy precipitation, which eventually trickles down into flash floods that have already claimed human lives (Khedo, 2013).

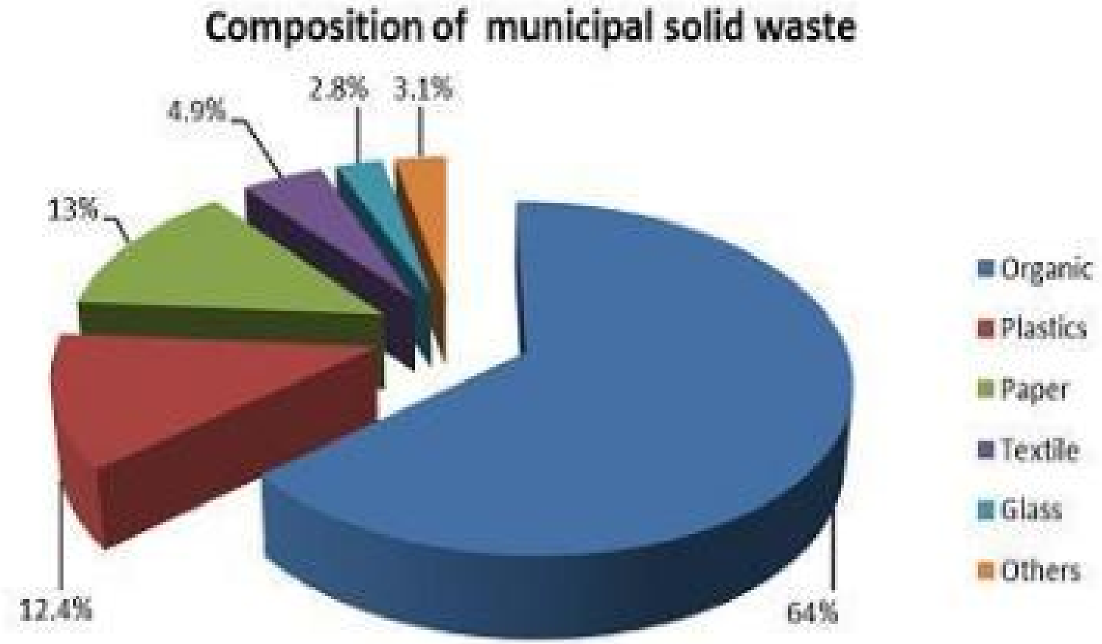

Figure 1. Composition of solid municipal waste, from the Ministry of Environment on sustainable development, disaster, and beach management (Image sourced by the Author).

From a people's perspective, culture is a driving force for sustainability as depicted by number 11 of the United Nations Sustainable Development Goals (Norström et al., 2014). However, despite Mauritius is an acclaimed melting pot of cultures, the capital city fails blatantly to exploit such a powerful driver for sustainability. Culture is a factor that adds vibrancy and life to a city, yet the lack of prominent green spaces and dedicated pedestrian areas, coupled with traffic jams and a noisy atmosphere, prevents any spirit of enhanced livability and hinders the right sustainable attitude (Guttee, 2015).

The island has reliable Internet connectivity from major service providers. For instance, as of March 2017, Mauritius had an Internet connectivity rate of 62.7% of the overall population, which makes it fourth on the whole African continent, behind Morocco (57.3%), Seychelles (57.6%), and Kenya (81.8%) (Internet World Stats, 2017). This might offer potential for introducing ICT-based monitoring of key indicators like transport, energy, and water dimensions, and hence provide real-time feedback for city controllers to readdress day-to-day strategies in an attempt to enhance the performance of the city. Such a concept forms the substance of smart cities (Helal, 2011; Hollands, 2008), but to really venture into a framework for smarting Port Louis, one needs to understand the dimension of smart cities.

Defining smart cities

The amalgam between the two words "smart" and "cities" brings forth several dimensions that encompass interconnectivity, resilience, and productivity while being conspicuous and sustainable (Riva Sanseverino, 2014). Kourtit, Nijkamp, & Arribas-Bel (2012) posited the dimension of smart people that infuse their creativity coupled with technology to enhance innovation and drive the productivity of smart cities. Townsend (2013) highlighted the concept of real-time monitoring and feedback mechanism regulation through the use of ICT, while Batty et al. (2012 as cited in Kitchin, 2014a) added the dimension of models generation through ICT-based urban setup for simulating future scenarios. Networking among stakeholders emanates from such ICT core for real time data processing from various key indicators. Nevertheless, the economic progress must not happen to the detriment of livability and happiness of urban dwellers. The human dimension must be at the very heart of smart cities (Dominici, 2012).

Smart city in the Mauritian context is being visualized and defined as self-sustained work in a live-and-play urban context, meticulously controlled by state-of-the-art connectivity systems offering a smart transportation system (Board of Investment–Mauritius, 2016). An understanding of how the notion of smart city has been impregnated within the minds and words of urban stakeholders is crucial to the unfolding of the proposed framework.

Evolution of ideas from a classic urban setup to a smart one

Smart city aims at integrating 21st century technology towards the betterment of urban life quality. To infuse such a concept within the century old foundations of Port Louis will entail a Herculean task. To smooth such a vision and hopefully, a soon-to-be mission, let us ponder the primordial soup that engendered such a concept. Understanding the origins might provide tangible indicators of where to gear the framework formulation for Port Louis. Greenfield (2013 as cited in Kitchin, 2014a) postulated that the foundation for smart city concept came to light within mid-20th century high modernist urban planning. However, Bollier (1998) claimed that such an appellation came into existence through the Smart Growth drive during the last decade of the 20th century. Such a view has been further supported by other studies (Vanolo, 2013; Wolfram, 2012). Kitchin (2014a) postulated that the smart city concept is a technological revisit of neo-liberal urban ideologies together with the very conception originating from the advent of ICT into urbanism, and fervently warned about the hidden agenda of ICT-pro companies that advocate for better humane urbanization while their main concern is the capital derivatives of smart cities. This Author also drew a thick line under the possible technocratic control that ICT-based monitoring might offer to governmental bodies. On a rather contrasting standpoint, other studies see the potential benefits of smarting cities (Letaifa, 2015; Kourtit, Nijkamp, & Arribas-Bel, 2012; Riva Sanseverino, 2014), but we should carefully avoid any potential loopholes that the smarting up process may pose.

THEORETICAL BACKGROUND

Cognizance for smarting up cities is gaining global momentum and literature details various models used for such a goal. One model that integrates human dimension in a pronounced manner is proposed by Nam & Pardo (2011). They reviewed evolutionary dimensions of cities throughout literature and brought in the three main factors they consider fundamental for a smart city approach (Figure 2).

Technology factor

The technology factor is ubiquitous in every smart city models due to the integral ICT component that offers a transformative power within city life (Hollands, 2008). Batty (2013) hailed technology in its ability to make sense of “big data” and hence allow better urban

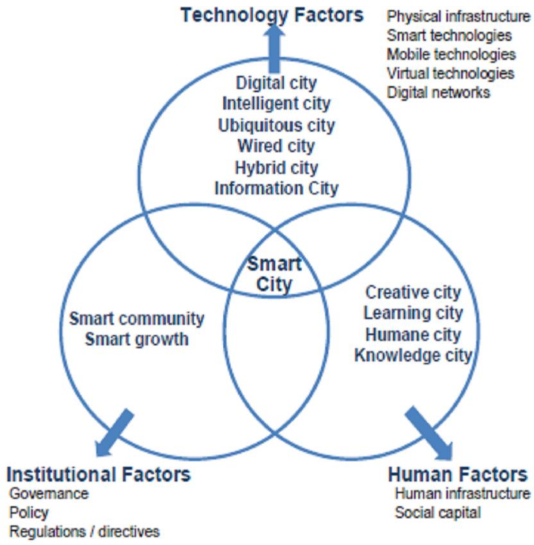

Figure 2. Smart city essential dimensions, Nam & Pardo, 2011 (Image sourced by the Author).

decision-making. The concept of big data generation within a smart city has also been praised as improving the life quality of citizens (Boulos & Al-Shorbaji, 2014). However, there are potential risks associated with the availability of data on how the city interacts that could lead to confidentiality and privacy issues (Batty, 2013; Kitchin, 2014b).

A sword of Damocles hanging on the balance is the need for a huge technical input from engineers to maintain an Information Technology (IT) infrastructure within a smart city. This could be achieved through the implementation of sensors to each energy-consuming component within the city to understand the evolution and dynamics of the energy profile of a city. Helal (2011) extrapolated on his vision of IT within smart cities by coupling the need of an IT footprint with the integration of a new generation of embedded operating system within each sensor. These new operating systems will allow the whole IT infrastructure to be interconnected in real-time similar to an ecosystem. Such smart operating systems for smart IT components will unleash the full potential of the technology component within an urban setup. Nam & Pardo (2011) recognized the positive influence that such technologies will provide to city residents. Nonetheless, ICT and the technology components may be hallmark features of smart metropolises, but without a proper institutional framework in terms of governance and regulations, the whole system may collapse (Helal, 2011).

Institutional factor

Chourabi et al. (2011) identified governance as one key dimension of smarting a city. This line of thought is shared by Paskaleva (2009) who proclaimed the central role of electronic governance (e-governance) as a driver for an emerging smart city. Nam & Pardo (2011) went further and highlighted that a smart city is not only a status, but also a continual progress originating from the very core of the city itself. These Authors stipulated that evolution in managerial strategies and policy-making is a key stage towards smarting a city.

The huge amount of big data fed into the system from the numerous sensors of the ICT infrastructure needs to be analyzed and used judiciously to meet the demands and vision of the city. This is where the institutional factor comes into play. Deakin, Lombardi, & Cooper (2011) reviewed the central role played by e-governance in light of the IntelCities Community of Practice (CoP) for electronically instilled services across European cities.

These Authors highlighted the enhanced dimensions that e-governance will provide to its citizens in terms of: i) upgraded data quality; ii) a round-the-clock supportive service to citizens and trades; iii) promotion of a state-of-the-art urban management system through a network of local authorities, regional governance, and utility providers, and iv) enhanced participative role of customers (citizens and trades) in a more inclusive decision-making process. However, there is another side of the governance coin. Data being provided from the city can be wrongly utilized by the governing bodies in various ways. Several Authors warn about how the huge flow of real-time data will make patterns predictable that may, in a worst-case scenario, give rise to a form of surveillance within a technocratic governance (Kitchin, 2014a; 2014b). Haque (2012) extrapolated on the availability of data as a means to propose an algorithm-processed governance, which might be used as a shield by governing bodies against ethical claims of dubious decisions. Kitchin (2014b) has shed a note of caution for such governance, which he described as being "narrow, reductionist and functionalist".

For instance, technocratic governance fails to consider the cultural dimensions of a city within the delicate balance of policy and politics, hence algorithmically processed governance will not be able to address the root cause of problems (Kitchin, 2014b). Vanolo (2013) put forward the "moral obligation" that needs to be displayed by citizens as being instrumental for a smart city to flourish. This lays the onus on the human factor within smart cities.

Human factor

Barrionuevo, Berrone, & Ricart (2012) recognized the essential role of the human factor in any urban progress. They stressed three crucial factors that the human dimension infuses into urban development: i) participation; ii) intelligence, and iii) proactivity. Nam & Pardo (2011) explicitly highlight the importance of human capital in smart cities because it catalyzes change through infusion of creativity and education. This view is shared by Malek (2009) who introduced the concept of "humanware" as a key indicator for development of smart cities through the "Informative Global Community". Also, Letaifa (2015) exalts the role of social capital acting as a "smart people" impetus. Smart is the diversity of ethnicity and cultural background, and the values pertaining to "tolerance, creativity and engagement". Aribilosho & Usoro (2016) related the human factor and the way it interacts in smart cities as being a "serious factor" for efficacy.

Though literature stressed the relevance of ICT-infused infrastructural components and e-governance, it should be clear that the purpose of the smart city is not to build a market by creating demands for state-of-the-art technologies. The goal is rather sustainability in the wake of such grim predictions for humankind based on climate change indicators. Thus, the human capital factor should be at the very core of any model aimed at smarting cities (Dominici, 2012).

Cohen (2012) has proposed another model, which greets the central position of people within a smart city setup (Figure 3). This model is depicted as a wheel with six spokes that highlight six dimensions of a smart city: i) smart people; ii) smart economy; iii) smart environment; iv) smart government; v) smart living, and vi) smart mobility.

Cohen's six pillars are further broken down into three indicators each (Figure 3). For instance, a smart economy revolves around innovation, entrepreneurship, productivity, and internationalization of markets, while achieving a smart environment involves adoption of green energy, buildings, and urban planning. This model caters to smart living by highlighting the need to achieve a culturally

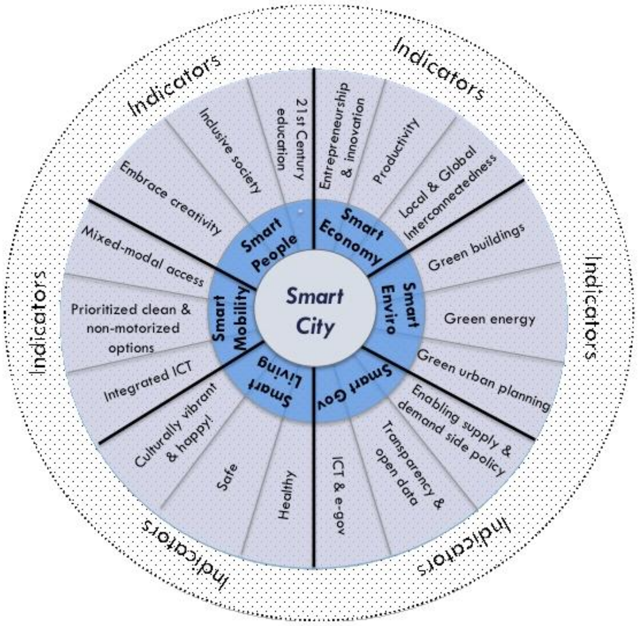

Figure 3. Cohen (2012) smart cities wheel (Image sourced by the Author).

vibrant society with a prime focus on heightened quality of life. In the same line of thought, Cohen's model calls for smart mobility and smart governance. These need the right policies and transparent data flow within an ICT infused e-government environment. Cohen also calls on smart people to focus on creativity within an inclusive society and the right educational setup. Lekamge & Marasinghe (2013) reviewed Cohen's model in light of its implementation as proposed by the Author himself. The first step involves setting up a vision, which takes into consideration the current state of the city and where it wants to position itself. Furthermore, baseline data needs to be collected and analyzed with an appropriate target and set course of action. The latter can be achieved through the adoption of best practices of existing cities, but Cohen warns to consider the uniqueness of each city in terms of population density, topography, and existing infrastructure. Moreover, Cohen (2012) stresses clearly the need to set achievable targets while proposing a long-term course of action.

Literature points out to some key providers such as IBM, which focuses on a tripod model. This includes: i) the people; ii) the infrastructure, and iii) planning and management (Figure 4). IBM (n.d.) explains planning and management as "long-term insights based on comprehensive data analysis, followed up through efficient daily management, [that] help a city stay vital and safe for its citizens and businesses". The five key indicators for such a pillar in IBM's model include: i) public safety (emergency management); ii) public safety (law enforcement); iii) smarter buildings; iv) city planning and operations, and v) government and agency administration. The infrastructure dimension of IBM's model consists of three main themes acting as key indicators: i) water; ii) transport, and iii) energy. In all previous models discussed above, people form a major pillar with key indicators revolving around: i) social programs; ii) healthcare, and iii) education.

On the same course of action, Hitachi uses a human-centered approach to smarting up cities aimed at: i) improving quality of life through better public safety within an economically viable and sustainably vibrant community; ii) increasing resiliency that promotes quick adaptability to immediate changes while being proactive on long-term issues, and iii) operating efficiently through

Figure 4. IBM (n.d.) smart city model (Image sourced by the Author).

smart use of technology, while cutting down on energy consumption and optimizing transportation times (Hitachi, 2016).

Based on the above literature, it is apparent that smarting up cities can happen through various models, but all have an ICT core aimed primarily at enhancing livability. To be able to choose one that will be most adapted for the capital city of Mauritius, we need first to understand the uniqueness of Port Louis.

FRAMEWORK FOR PORT LOUIS

In a bid to integrate Port Louis people within the smarting up process, and ensuring achievable goals through a "go lean" approach as preconized by Cohen (2012) I have considered to focus on the IBM model.

Key is the human capital of the city. The mission is to promote the capital of Mauritius as a vanguard smart city with smart people in a smart setup geared towards state-of-the-art living standards. It goes without saying that this vision needs to be scrutinized by scholars within various fields, but also by the residents and workers of Port Louis. Such an aim extends beyond the scope of this paper to open avenues for future venture. Once the vision is set, the dimensions of the smart city within the selected model need to be clearly stipulated.

The People

For this dimension, key indicators identified are i) social programs; ii) smarter care, and iii) education. Besides offering a melting post of cultures, Port Louis is punctuated with several historical landmarks including the UNESCO world heritage site and the Aapravasi Ghat. Moreover, the human dimension of Port Louis includes commuters from several other districts together with the local population (Table 1). Human infrastructure concerns social learning and education (Nam & Pardo, 2011). Social learning is based on a theory proposed by Bandura (1971) that principally argued that the learning process can occur by observation within a social setup. The social setup is the cultural identity of the capital city with its historical sites.

The cultural glue of such process is sustainability. It needs to be conspicuous enough to reach the population. This is where Maslow's hierarchy of needs is useful. Maslow's hierarchy of needs (Lekamge & Marasinghe, 2013) is a series of dimensions that drives someone towards a certain behavior. The most fundamental dimension is physiological need, whereas the most essential is self-actualization.

This is in line with the proposal of Lekamge & Marasinghe (2013) who stipulated that no progress can be achieved if the needs and wants of citizens are not met. In order to move in such a direction, a well-established theoretical framework must act as anchorage, and so Maslow's hierarchy of needs has been proposed.

For Port Louis, the education within a social setup is more informal and attitude-based. Since the focus is on smart setup, there should be reinforcement of such an approach by designing tailor-made campaigns to inculcate the values pertaining to an ICT-infused culture within a smart setup. For instance, Krätzig & Warren-Kretzschmar (2014) lauds the opportunities that social media, like Twitter, can have in participatory planning and communication.

Unlike megalopolises where most of the inhabitants stay within the same city they work, Port Louis experiences a huge number of commuters coming from other regions everyday (Table 1). The focus on sustainable education within a smart setup should therefore be a national drive. In promoting an education for inculcating sustainable culture, several factors should be considered. In the wake of the 21st century, with the huge opportunities that ICT provides and with the Z generation of students, the whole teaching and learning process should be readdressed. Beetham & Sharpe (2013, p. 6) recognized such a need and argued that two dimensions of education should be pondered, i.e. pedagogy and design. These two dimensions will promote a contextualized 21st century educational system to introduce the values of sustainability within a smart setup. So do Nam & Pardo (2011) when urging to promote ICT within the core of educational curriculum.

The human factor within a smart city also includes creativity and a social capital dimension. Simpson (2005) postulated social capital as positive outcomes resulting from core community-based values backed by strong social networks, sense of belonging, and committed leadership. The Author further explained that robust social capital is achieved by the recognition of diversity and through adoption of a socially inclusive community. Effective ICT skills are essential to promote the concept of social capital (Simpson, 2005). To achieve such a crucial step for Port Louis, citizens and people coming to work need to feel this sense of belonging. Port Louis should be appealing, safe, and conspicuous. The heavy, noisy traffic and the lack of pedestrian friendly zones, green spaces, and upgraded living environments make the capital city very far from conspicuous (Guttee, 2015). As such, a SWOT analysis has been carried out to highlight the key strengths, weaknesses, opportunities, and threats that the people in the chosen model may offer (Figure 5).

The SWOT analysis for the people dimension highlights that core strength and opportunities reside on the cultural diversity of Port Louis and the possibility to introduce educational reforms. However, cultural diversity may also be a threat owing to the inherent difficulty of satisfying the needs for each socio-cultural group in the capital city. Moreover, education policy cannot be applied to one city only but should be a national drive. Despite stakeholders strongly want to move ahead

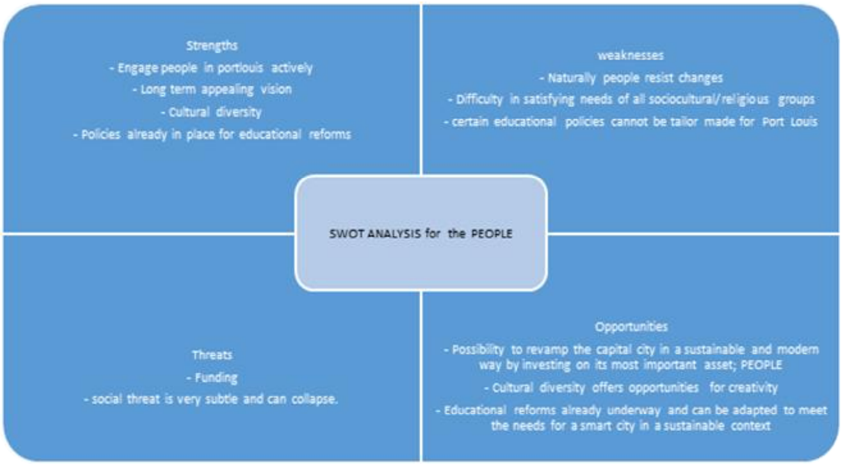

Figure 5. SWOT analysis for the human dimension (Image sourced by the Author).

and smart up Port Louis, issues of funding is a hindrance. There needs to be public-private partnership to provide the means to investing in human capital as proposed by Vanolo (2013). Although the human dimension holds a key place in the proposed model for Port Louis, nothing can really be achieved if there is not thorough planning and management to gear the city towards its smart vision.

Planning and Management

Smarting up the city will entail data. The huge flow of data that is generated in a smart city needs proper policies and governance to be meaningfully utilized. This dimension of the proposed model for Port Louis has four key indicators in the form of: i) public safety, ii) government and agency administration, iii) city planning and operations, and iv) buildings. Governance for a smart city needs to serve the demands of the community, but this should occur within a proper policy framework. Allwinkle & Cruickshank (2011) highlighted the central role of government in the Amsterdam city project aimed at saving energy and studied e-government in Edinburgh. They showed that governance is mainly linked with the vision. Singapore's model could be helpful in this respect. The main asset of Singapore has been its people, and how the government has focused on developing policies for promoting human and social capital with key guidelines for a sustainable culture. These sustainable programs aimed principally at reducing greenhouse gas emissions and traffic in a bid to enhance livability (Kogan & Lee, 2014), a goal that Port Louis must also share.

Another major dimension of governance is transparency and open data. Nam & Pardo (2011) strongly highlighted the need for the government to share a vision and even a strategic plan with all the stakeholders. Moreover, these Authors show the need for strong leadership at the helm to guide any city through the smarting up process. Strong leadership will promote interrelatedness among all the stakeholders, while keeping the way data and policies are being processed in full transparency. A SWOT analysis has been performed for this dimension to shed some light on potential loopholes and avenues for advancement.

Based on the SWOT analysis (Figure 6), it is quite apparent that there are serious strengths and opportunities to drive the planning and management process ahead through active public-partnership as said by Nam & Pardo (2011) and Vanolo (2013). However, not all policies may be

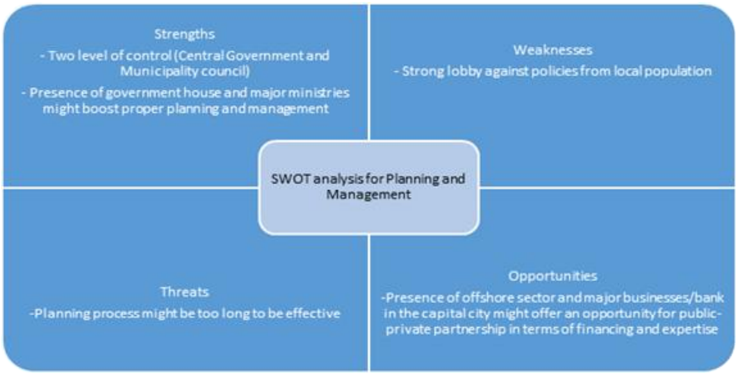

Figure 6. SWOT analysis for Planning and Management (Image sourced by the Author).

fully accepted by the local population and this could lead to some strong resistance. Such resistance might eventually hinder the planning process and if this extends over five years and a new administration comes into power, then the planning process may even turn out to take more time. Although human factors and institutional dimensions have major parts to play in turning the capital city of Mauritius into a smart one, there needs to be a state of the art ICT core within the very foundations of any framework for such an endeavor.

Infrastructure

Infrastructure remains a central issue. Connectivity through Web 2.0 technologies propose infrastructural challenge for smarting up the capital city of Mauritius. Such an aspect needs to be cared for in order to integrate systems that will lead to smart management of water, energy, and transportation indicators falling under such a dimension of the proposed model. Lövehagen & Bondesson (2013) offered specific guidelines for impact assessments of ICT key indicators. They suggested that key indicators be manageable with data sets from which baselines could be defined within a transparent setup. Moreover, these Authors insisted on the need for clear data of life cycle dimension for ICT solutions together with realistic aftermath consideration for implementation of any urban ICT component. Once the sustainability component has been resolved, one can consider the transformation that ICT will provide for Port Louis.

Mauritius boasts high-speed internet connectivity, and this trend has kept increasing for the past decade. Enhanced connectivity is crucial for a smart city. However, there are other key indicators to consider. In that sense, Schaffers et al. (2011) proposed the concepts of smart transport, smart grid and environmental monitoring.

Port Louis is congested and has few parking spaces available during the daytime. This creates a noisy environment coupled with enhanced greenhouse gas emissions. The dense urban setup delimits wind flow resulting in an over-dependence on air conditioning for both residential and business buildings. Solutions exist and some are already being substantiated, like the introduction of a metro system to alleviate the transport situation and the introduction of the Sea Water Air Conditioning System (SWAC), which uses cold water from the ocean for air-conditioning (OTEC Foundation, 2014).

Smarting up Port Louis will entail the introduction of monitoring systems with a smart management system to promote enhanced productivity and performance within an upgraded livability core. To meet such an end, Gubbi, Buyya, Marusic, & Palaniswami (2013) proposed the use of a Wireless Sensor Network (WSN) that offers real time data capture. These data could subsequently be analyzed to promote a Common Operating Picture (COP). Such an integrated system is what the Authors referred to as the Internet of Things (IoT) and they lauded its potential application in a smart environment context for the welfare of citizens in the City of Melbourne (Table 2). Implementation of such an integrated system for Port Louis needs to be considered within the right institutional (governance and policy) setup embedded within the ties of transparency and accountability to make the capital city of the island smart.

Citizens	
Healthcare	triage, patient monitoring, personnel monitoring, disease spread modelling and containment - real-time health status and predictive information to assist practitioners in the field, or policy decisions in pandemic scenarios
Emergency services, defence	remote personnel monitoring (health, location); resource management and distribution, response planning; sensors built into building infrastructure to guide first responders in emergencies or disaster scenarios
Crowd monitoring	crowd flow monitoring for emergency management; efficient use of public and retail spaces; workflow in commercial environments
Transport	
Traffic management	Intelligent transportation through real-time traffic information and path optimisation
Infrastructure monitoring	sensors built into infrastructure to monitor structural fatigue and other maintenance; accident monitoring for incident management and emergency response coordination
Services	
Water	water quality, leakage, usage, distribution, waste management
Building management	temperature, humidity control, activity monitoring for energy usage management Ð Heating, Ventilation and Air Conditioning (HVAC)
Environment	Air pollution, noise monitoring, waterways, industry monitoring

Table 2. Potential IoT applications for the City of Melbourne
(Gubbi, Buyya, Marusic, & Palaniswami, 2013) (Table sourced by the Author).

A SWOT analysis for the infrastructure dimension offers further insight into the third pillar of the proposed model for smarting up Port Louis (Figure 7).

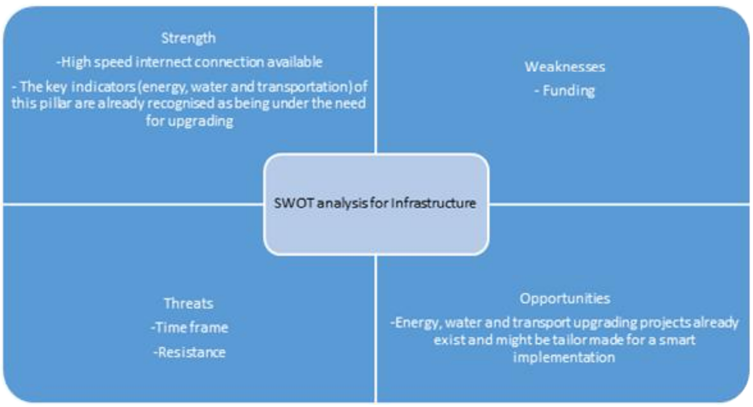

Figure 7. SWOT analysis for infrastructure domain (Image sourced by the Author).

The major strengths and opportunities for the infrastructure pillar of the IBM model revolves on the fact that studies have already been conducted on all three key indicators of such a dimension

(Welsch et al., 2014) and simply need to be tailor-made. For instance, Mauritius has tremendous potential in developing renewable power sources such as wave power, ocean thermal energy conversion (OTEC, 2014), solar photovoltaic, and wind power (Hammar, Ehnberg, Mavume, Cuamba, & Molander, 2012). Further, Khoodaruth, Oree, Elahee, & Clark (2017) point to the possibility of enhancing the self-sustainability of Mauritius for energy. As said before, however, a major hurdle remains the cost, the resistance from local population, and the time schedule of projects for efficient implementation. One possibility to circumvent the funding issue, besides looking for public-private partnership, is to pay for the service rather than pay for the whole setup. Such a solution exists, e.g. Hitachi offers smart transport solutions as a service (Hitachi, 2016). Resistance from local population and timeframe issues can be alleviated through proper planning and management of the system.

The next step in the smarting up process needs a proper model for efficient implementation. To this end, the SMART model (Figure 8) proposed by Letaifa (2015) has been noted. It works at micro, meso, and macro levels and encompasses all three dimensions of the IBM proposal while placing citizens at the very core of the smarting up process. On the macro level, the focus is on scope and mindset upgrading by developing a proper strategy within a multi-disciplinary team backed by strong political sponsorship under expert leadership. Meso level will involve appropriation of the project by key actors and generation of roadmaps to meet the end of the smarting up endeavor. Eventually, on the micro level, the right technology will be identified and projects launched for their smooth integration. At all levels, the focus must be on transparency, accountability, and performance.

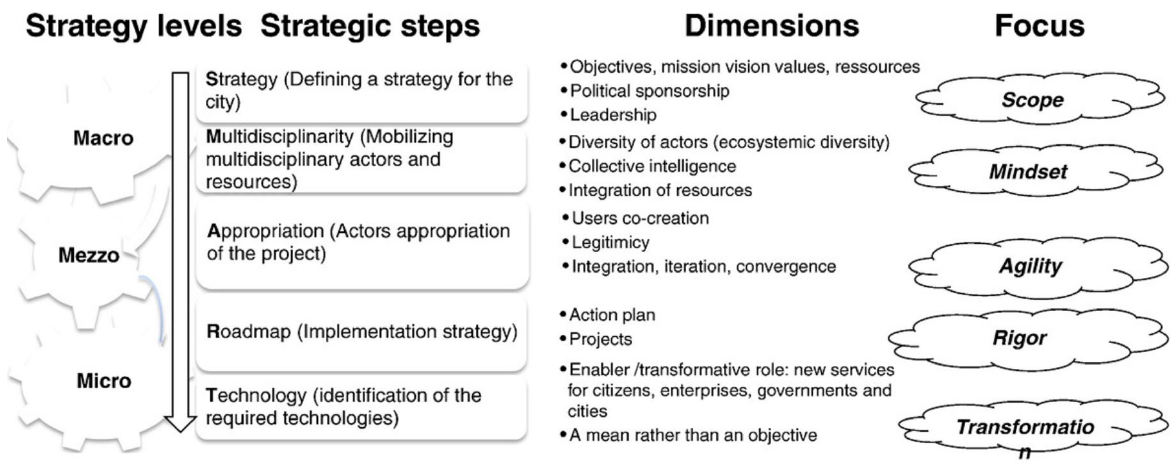

Figure 8. The SMART Model (Letaifa, 2015) (Image sourced by the Author).

CONCLUSION

The aim of this study is to propose a conceptual framework for smarting up the capital city of Mauritius based on the IBM model. Such a model consists of three major dimensions: i) people; ii) planning and management, and iii) infrastructure. Each dimension comes with specific indicators. For instance, the people dimension lays emphasis on social programs, education, and smarter care, while energy, water, and transportation issues are showcased under the infrastructure banner. The planning and management pillar revolves around indicators linked to public safety, government and agency administration, and city planning and operations together with buildings within the city. For a smooth implementation, the SMART model has been proposed, which caters to macro, meso, and micro levels of the smarting up process. One needs to consider all the strata of policy and planning within Port Louis while respecting the chain of command through efficient leadership and regulation at every stage of the smarting up process.

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DISCUSSIONS & REVIEWS

Kaide [Plinth]

Aslıhan Demirtaş. (2016–2017). *Kaide [Plinth]* [Rammed earth]. Istanbul, Turkey.

Review by Sara Bissen
The Ruralist Body, United States of America

Kaide in Turkish means pedestal, principle, rule, or foundation. In Ancient Greek *kaide* refers to *plinthos,* which is a brick, i.e. baked earth. From architecture, a plinth refers to the base that supports the symbolic column of truth in both Eastern and Western culture. The soil, which is alive, is the principle, and building begins from this foundational truth.

Aslıhan Demirtaş created *Kaide [Plinth]* from 1.5 tons of soil, clay, flax fiber, fine grain Küfeki stone (a type of limestone local to Istanbul), and terracotta to form a rectangular parallelepiped of 1m x 1.5m x 0.55m of rammed earth. Its shape resembles a *bostan* from the 1,600-year-old Yedikule Gardens cultivated along Istanbul's historic walls. Demirtaş's activism has involved protecting these time-honored vegetable gardens from municipal demolition for the purpose of "culture" and tourism. *Plinth* also reminds one of the earth covered tombs in Istanbul's cemeteries where the plant life flourishes with the afterlife. The land is rooted, but *Plinth* may be a symbolic turning of soil that moves at the base of the city.

Plinth first appeared as *Nâkil* in the comprehensive project *Umulmadık Topraklar* during the 26th ARTİST/İstanbul Art Fair together with the city's Association of Archeologists (Arkeologlar Derneği İstanbul Şubesi) and the KHORA design team. From November 12–20, 2016 this rammed earth platform uncovered how traces of soil have been carried through migration. Later curated by Özge Ersoy at Collectorspace, *Kaide [Plinth]* was installed and held near Istanbul's Taksim Square between March 8–May 31, 2017. Nazım Can Cihan and Sadık Atar formed the earthen brick while photographer Ali Taptık documented the process of making and un-making the prism. Demirtaş invited farmers and artists to engage with the installation. Each person offered words or materials from their own collection practices (Demirtaş, 2018). The soil taken for *Plinth*'s formation was returned to its source. Inquiries into value, tangibility, and preservation emerged from this relationship.

Farmers' hands have touched this old, deep relationship that lies within the base of our civilization. Despite today's financial city, *Plinth* awakens the fundamental memory of body as soil. Displacement is one issue at the heart of Demirtaş's material investigation. Subject to the demands of capital, e.g. financial dispossession in Istanbul today, urban consumption anticipates the disappearance of both the farmer and the soil (Bissen, 2015, 3, xxx–xxxiii). One reality of this flow is the movement of people from rural Anatolia to Istanbul, not to mention Kurdish forced migration and internal displacement. *Plinth* surfaces at a time and in a place where every parcel of land is eaten, even beyond itself. Afrin is only a single, latest example. Demirtaş questions mobility within the contemporary cultural condition. She asks, "what if everything else changes around you—how do you become a refugee without even moving an inch?" (Demirkazik, 2017). This feeling can be found today in the aggressive development not only of Turkey but also of the urban core of the U.S., Italy at the half of the 20th century, or anywhere rurality has become a sliver of society—by either moving or staying.

Photograph by and courtesy of Ali Taptık, Onagöre, 2017.

In fact, as highlighted by Demirtaş, urban land can be displaced because living "soil cannot be uprooted and displaced into a constructed whole" (Bissen, 2015, 3, [cclxci–cclxcii]). While "the city is the most effective tool for making images" (Ibidem, 2, [xlii]), the "soil is not an empty box to be filled" (Ibidem, 3, [cclxxxviii]). Through *Plinth* and beyond artifacts, Demirtaş finds that the rural in the city is not to be made into the nonliving (Demirkazik, 2017). Like money or financial capital, if the soil structure is reproduced without its principle, then it flows away from the root. Picked up, used, and disposed of, soil may be lost to sanitization. Such a packaged product may have only one way out and its direction is present in the cracks of soil. At the surface, the earth opens “for a logic to emerge from beneath the layers of absolute knowledge” (Bissen, 3, lxxiv). *Plinth*’s weathering has shown this (Demirtaş, 2018).

Rural is a principle of urban civilization. Soil is a principle for the rural. Biophilic design seems an excessive category as long as soil remains the plinth of our society, meaning we might “lose the ability to feel nature, and feel only its reproduction” (Bissen, 2015, 2, xcvii). Soil and body are alive and living as threats to this system of financial dispossession. *Kaide [Plinth]*, in the form of a new rammed earth space, will be installed in Beyoğlu, Istanbul. Demirtaş remains an artist who acts at the site of tension.

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Small Urbanism for Evolving Cities and their Parts

Bernd Upmeyer (Ed.). *Small Urbanism. MONU Magazine on Urbanism, 27*(October 2018).

Review by Amy Tibbels
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“To find a form that accommodates the mess, that is the task of the artist now.” This 1961 quote from Samuel Becket has been used by Marco Casagrande in his article “From Small Scale Interventions to the Third Generation City” for the 27th issue of *MONU: Small Urbanism*.

What are cities in relation to their parts? This latest issue of MONU shows that the small can be found within many elements of our cities, from GPS satellite networks down to the beat of curb cut raptures. The small often is, as Bernd Upmeyer warned in his call for submission, almost not there. A discussion surfacing within MONU’s concept of Small Urbanism—worth further thought—is the transpiring role of the “small” for the recoupling of our cities. Whether characterized by the act of reforming, saving, reordering, tuning or healing, a number of contributions labor towards an understanding of the intricate relationship cities share with their fragments.

I first became aware of the issue’s themes and situational relevance while reading Julian Oliver’s article “Stealth Infrastructure” (p. 73). Oliver depicts a wistful image of telecommunications in 1980’s rural New Zealand. With one phone line running through his community, individuals would sensibly answer only to their particular call pattern. This system emerged entirely from an open infrastructure of trust, and it seems inconceivable nowadays in the age of cell phone towers. Oliver cautiously approaches the advance of an increasingly invisible infrastructure with an embodiment of fragility. He paints cities as “cradles”, composed carefully of “knitted infrastructure” that support our way of living.

“We’re reminded that our cities are engineered and technical places as much as they are natural expressions of the Human and the Social… What we expect from infrastructure is that it works, because when it doesn’t, it isn’t.”

Oliver indicates that it is only when a spot of weakness appears, and the city’s infrastructure is revealed, that we may perceive how monumental such a seemingly small or undetectable element of our cities can be.

Almost in opposition to the fragility illustrated by Oliver, Nicholas de Monchaux applies a robust focus toward the possibilities of a digital resilience in his article “Local Code: Real Estates” (p. 86). According to de Monchaux’s Local Code project, architecture and the city could be the instrument for an “information-inspired physical resistance”. Covering 3,659 abandoned sites over four cities, his research maps sites sharing overlapped circumstantial characteristics, foremost a potential for “most transformative” ecological remediation. De Monchaux advises that since abandoned sites have accumulated in areas where public green space is normally denied, the benefits of these small instillations would translate greatly to public health and wellbeing. Advocating his prospect, the Author asserts that in order to make a robust and resilient city,

> …it is only through understanding and engaging the existing nature of our cities as complex, networked artifacts that we can design for, and imagine, a robust and resilient future for them… built into and out of the city itself.

De Monchaux's work brings forwards the significant notion that digital science methods within urban research can provide powerful proof for greater influence, and this comes particularly with an attitude for envisaging fragments of the city and urban strategies in concert.

In the interview "Every Object Is a Crowd!" (p. 40), philosopher Levi Bryant discusses his theory of the "democracy of objects". For understanding the city, it is of benefit to think of it to be "no less an object than a mailbox or a quark." In an ontological framework, this may provide problems. However, to then understand these "objects" as composites of others, and the complexity this ensues is where Bryant offers an attitude that is echoed in many other articles of the issue.

> Somehow the city emerges out of this crowd, out of this complexity, both depending on them for its existence, while also being independent of them. And likewise for all the objects that compose the city… we shouldn't treat the smaller elements of an object as subordinate to the larger-scale object.

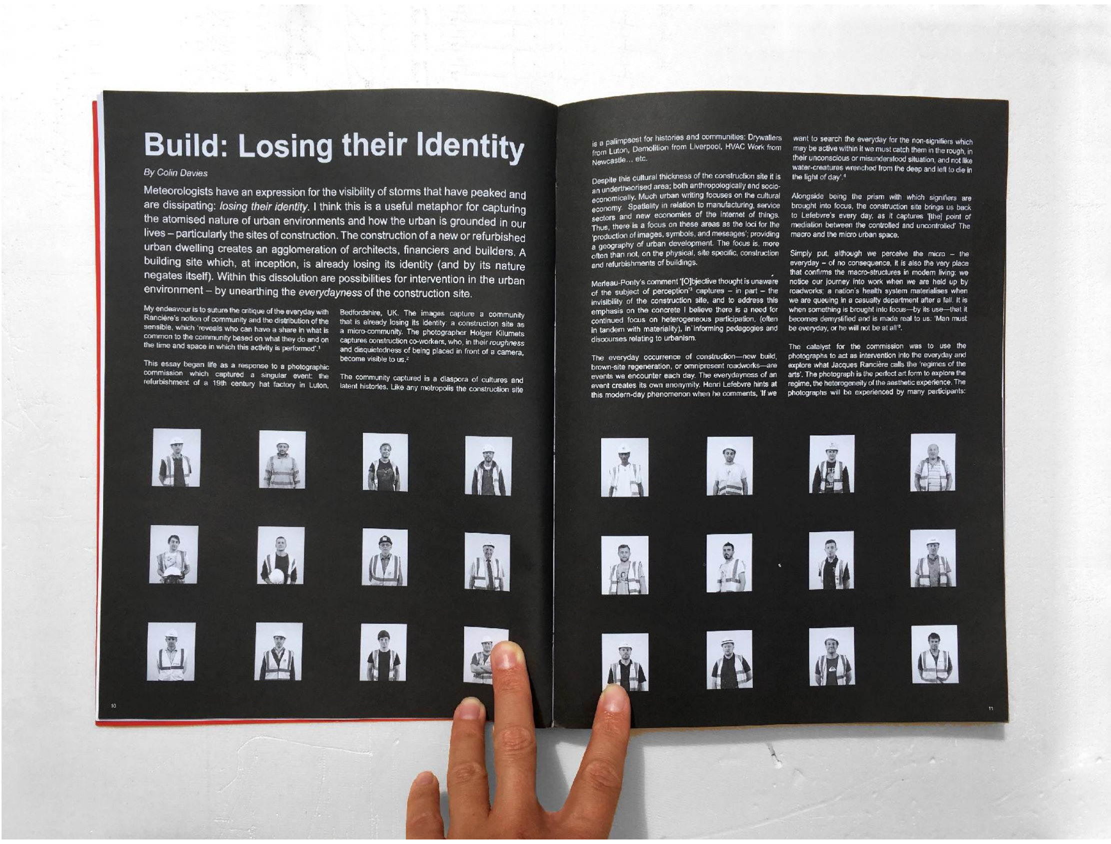
This mutual affiliation and dependence Bryant assigns to cities and their fragments, supports de Monchaux's assertion that information, cities, and resilience are all essential and exist in concert. It also lends significance to the dialogue between de Monchaux and Oliver, providing that the fragile infrastructure and networks of our cities can perform not as subordinate, but as the tool to reform a robust city.

Bryant's assertion can easily be likened to Henri Lefebvre's theory of the everyday, where the micro and macro are proposed as mutually irreducible scales. Colin Davies fittingly situates this thought in the mundane, within his article "Build: Losing their Identity" (p. 10). Here Davies exhibits a catalogue of construction worker portraits—a relatively commonplace formation. In his article however, they are framed as an assemblage of people that, as Davies illustrates, "only exist as a micro community". The workers are a part of the mechanically reproduced city that they themselves help conceive. Davies' likening of their identity to a dissipating storm captures, as he states "...the atomised nature of urban environments and how the urban is grounded in our lives". This is an important view to showcase within the issue's other articles; it gives prominence to the human as within a dependent system, providing the group as a face of "small urbanism".

Marco Casagrande offers insight into the discourse of this issue with his studies of Taiwan in the article "From Small Scale Interventions to the Third Generation City" (p. 122). He, similarly to Davies, highlights the need for a shift in our human-centered systems. He asserts that material cycles of cities such as Taipei, have been in co-existence much longer than those of industrialism. Casagrande argues that the recoupling of cities will lie in the use of "Local Knowledge", which he promotes, will tune the industrial city towards the "organic machine". As questioned by editor Bernd Upmeyer earlier in one of the issue's interviews, "could small urbanism become our ecological savior?" Casagrande trusts the small urban fabric of communities, slums or favelas, as the origin of this seeded knowledge and the resurgence of the natural. Casagrande sees these small instantaneous "acupuncture points" creating large social and ecological ripples to work against industrialism and allow cities to evolve.

Casagrande, along with other contributors, boldly imagine what can come from thinking of the "small" in urbanism. Yet I suggest that perhaps for the thoughts in this magazine to be largely applied, we need to think even smaller. These discussions could benefit from leaking outside the pages of this issue, with application to investigations in construction and materiality. As an example, Rachel Armstrong's research promotes the reimagining of architectural fabric at a cellular level for evolving cities. Her research into the self-assembling "protocell" cultivates new capacities for building systems at such a small scale, while also advancing the use of intelligent codes from a mere surface tool. This kind of small construction, combined with optimism for urban and information technology as a systematic tool for resilience, and recognition of the city as interdependent to its parts, could provide a strong basis to build our cities in and out of themselves.

The latest issue of MONU is appreciatively dense with thoughts not only on the influence small urbanism has on cities, but on how cities really are in relation to their parts. Contributors write for social prosperity, political protest, infrastructural transparency, and militant ecology. Although independent from each other, every voice within the pages of issue 27 of MONU helps paint an image of the complexity of our cities and the methods we take to, in Becket's words, "accommodate the mess".



Build: Losing their Identity

By Colin Davies

Meteorologists have an expression for the visibility of storms that have peaked and are dissipating: *losing their identity*. I think this is a useful metaphor for capturing the atomised nature of urban environments and how the urban is grounded in our lives – particularly the sites of construction. The construction of a new or refurbished urban dwelling creates an agglomeration of architects, financiers and builders. A building site which, at inception, is already losing its identity (and by its nature negates itself). Within this dissolution are possibilities for intervention in the urban environment – by unearthing the *everydayness* of the construction site.

My endeavour is to suture the critique of the everyday with Rancière's notion of community and the distribution of the sensible, which 'reveals who can have a share in what is common to the community based on what they do and on the time and space in which this activity is performed'.[1]

This essay began life as a response to a photographic commission which captured a singular event: the refurbishment of a 19th century hat factory in Luton, Bedfordshire, UK. The images capture a community that is already losing its identity: a construction site as a micro-community. The photographer Holger Kilumets captures construction co-workers, who, in their *roughness* and disquietedness of being placed in front of a camera, become visible to us.[2]

The community captured is a diaspora of cultures and latent histories. Like any metropolis the construction site is a palimpsest for histories and communities: Drywallers from Luton, Demolition from Liverpool, HVAC Work from Newcastle… etc.

Despite this cultural thickness of the construction site it is an undertheorised area; both anthropologically and socio-economically. Much urban writing focuses on the cultural economy. Spatiality in relation to manufacturing, service sectors and new economies of the internet of things. Thus, there is a focus on these areas as the loci for the 'production of images, symbols, and messages'; providing a geography of urban development. The focus is, more often than not, on the physical, site specific, construction and refurbishments of buildings.

Merleau-Ponty's comment '[O]bjective thought is unaware of the subject of perception'[3] captures – in part – the invisibility of the construction site, and to address this emphasis on the concrete I believe there is a need for continued focus on heterogeneous participation, (often in tandem with materiality), in informing pedagogies and discourses relating to urbanism.

The everyday occurrence of construction—new build, brown-site regeneration, or omnipresent roadworks—are events we encounter each day. The everydayness of an event creates its own anonymity. Henri Lefebvre hints at this modern-day phenomenon when he comments, 'If we want to search the everyday for the non-signifiers which may be active within it we must catch them in the rough, in their unconscious or misunderstood situation, and not like water-creatures wrenched from the deep and left to die in the light of day'.[4]

Alongside being the prism with which signifiers are brought into focus, the construction site brings us back to Lefebvre's every day, as it captures '[the] point of mediation between the controlled and uncontrolled' The macro and the micro urban space.

Simply put, although we perceive the micro – the everyday – of no consequence, it is also the very place that confirms the macro-structures in modern living: we notice our journey into work when we are held up by roadworks; a nation's health system materialises when we are queuing in a casualty department after a fall. It is when something is brought into focus—by its use—that it becomes demystified and is made real to us: 'Man must be everyday, or he will not be at all'[5].

The catalyst for the commission was to use the photographs to act as intervention into the everyday and explore what Jacques Rancière calls the 'regimes of the arts'. The photograph is the perfect art form to explore the regime, the heterogeneity of the aesthetic experience. The photographs will be experienced by many participants:

Photograph by Amy Tibbels. Pictures in the photographed issue by Holger Kilumets.