AN INTERACTIVE LIVING SPACE – ANTICIPATION IN ARCHITECTURE

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ABSTRACT

Many years ago, Mihai Nadin[2] wrote about the architecture of dynamic structures. He made reference to the work of Superstudio (an architecture firm, founded in 1966 in Florence, Italy by Adolfo Natalini and Cristiano Toraldo di Francia) and Archigram (an avant-garde architectural group formed in the 1960s, based at the Architectural Association, London). But this article is not about the Radical Architecture movement, rather about a new way of thinking: anticipation was the backbone of conceiving spaces for maximum interaction (especially in educational institutions). When I started my research for a dissertation, his thoughts from the past were less on my mind than the opportunity to re-invent architecture for the professionals who were making the new technologies of interaction possible, but who found themselves deprived of appropriate housing. My research took place within the antÉ – Institute for Research in Anticipatory Systems, which he founded and directs. The anticipation perspective I adopted is about a new way of seeing reality and approaching the human being in its most significant aspect: creativity. My contribution to a celebration of Nadin's activity is in line with his dedication to make things happen, to make anticipation a useful tool. The following is a report I wish to add to the record of anticipation research.

KEYWORDS: architecture, anticipation, space, adaptive and flexible space, interactive space design, Virtual Environment, interaction, structural flexibility, spatial reconfiguration, spatial articulation.

1. Introduction: A Need for Anticipatory Architecture

The conditions of globalization—open markets, universal integration and assimilation of ideas, products and cultural views, unprecedented changes in communication, digital and social networks, innovative computer technologies reshaping the urban infrastructure, new waves of migration and multi-national identities—have led to the rise of a new class of workers labeled "neo-nomads." Similar to the traditional nomads, they are characterized by mobility and adaptability[3]. The mobility of neo-nomads entails not only physical displacement, but also mental displacement, that is, detachment from one's community and cultural roots[4]. As a cultural hybrid, the neo-nomads are a highly adaptable population that can establish a new sense of belonging in new contexts and situations, constituting their identity in the way they live and work[5].

These are the new-generation information technology professionals, entrepreneurs and freelancers. The best known among them are the Silicon Valley workers, but similar groups are identifiable in England, Germany, etc. They form a new breed of a highly mobile, technology-dependent, wireless population who can work and correspond remotely[6]. They are highly adaptive

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[2] Nadin, Mihai (1995) The Architecture of Thought, in *Living* (Architecture for the Third Millennium), 2:95. Cologne: Halem Verlag: 20–22.

[3] Nadin, Mihai (2010). Anticipation and the Artificial: Aesthetics, Ethics, and Synthetic Life, *AI & Society* 25:1 (April 2010): 103–118, doi:10.1007/s00146-009-0243-0

[4] Abbas, Yasmine (2004) Neo-Nomads and the Nature of the Spaces of Flows, *UbiComp in the Urban Frontier* Conference proceedings, September 2004. Nottingham, England: UbiComp 2004: 12–13.

[5] Nadin, Mihai (1997) *The Civilization of Illiteracy*. Dresden: Dresden University Press.

[6] Abbas, *op. cit*.

to new, dynamic settings, with no fixed sense of belonging[7]. The past decades have witnessed a rapid increase in the number of these tech-literate, young professionals and entrepreneurs—some coming from Eastern European countries, from Russia and other parts of what used to be the Soviet Union, from the Asian Subcontinent (India, Pakistan, Bangladesh, etc.), in pursuit of remote jobs at various technology hubs around the world[8]. The booming industry of internet, social media and smartphone technology of San Francisco, for example, experienced a recent influx of job growth that, in addition to space shortage and higher rent, has contributed to the severe housing crisis[9].

2. Research Overview

In view of this problem, research was undertaken into integrating architectural knowledge of space design with interactive system design in the field of habitable interactive architecture. A new design concept of an interactively modifiable living space is introduced as a real-world dwelling that consists of a single living space with variable design parameters of color, brightness, texture and material used to generate affective or emotional experiences of spaces. Through human interaction with physical space, occupants generate possible sensory-perceptive, affective spaces by means of spatial articulation in real time with the goal of accommodating their evolving emotional, psychological, physiological, and aesthetic requirements associated with daily activities. Here, spatial articulation—a space creation technique of traditional architecture—refers to modification of overall visual quality of space, i.e., character, feel, and appearance, by manipulating the variables of visual space perception. These variables generally include but are not limited to light, material, color and texture (Figure 1). In the input-output (action-response) mechanism of human-space interaction, living space articulates spatial quality in response to an occupant's perception or emotional responses to its affective dimensions.

For the purposes of this research, a Virtual Environment (VE) way used as an evaluation tool to find correlations between design parameters and perception. It evaluates the capacity of proposed design concepts to articulate spaces for creating affective spatial qualities. A six-sided immersive Cave Automatic Virtual Environment (CAVE)-type display was chosen to conduct a user study in the proposed living space simulated with adapted equivalent parameters of color, brightness and texture. As VR substitutes real-world sensory methods with equivalent two-dimensional graphical methods, it is important to find out if within its technological constraints VE can replicate the real-world affective space creation that are essentially multi-sensory and three-dimensional. In other words, the user study aims to find out if adapted design parameters have an impact on emotional responses, and to what extent they are comparable to real-world perceptions.

The result of the research was the formulation of an aesthetic framework for the interactive system to regulate the behavior of human-space interaction of the living space. This involved processing of received occupant inputs and articulation of possible affective spaces as outputs that are meaningful for occupants and can potentially support their psychophysiological needs. Databases for design parameters of color, texture, and material are constructed in association with design principles for the interactive system to use. Fuzzy logic system, a soft computation method,

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[7] Fost, Dan (2007) Where Neo-Nomads Ideas Percolate, *SFGate*, March 11, 2007 . http://www.sfgate.com/news/article/where-neo-nomads-ideas-percolate-new-2610920.php

[8] Hart, Anna (2015) Living and working in Paradise: The Rise of the Digital Nomad, in *The Telegraph*, last modified May 17, 2015. http://www.telegraph.co.uk/news/features/11597145/Living-and-working-in-paradise-the-rise-of-the-digital-nomad.html

[9] Hepler, Lauren (2014) The Shadow of Success: Inside Silicon Valley's Affordable Housing Crisis, *Silicon Valley Business Journal*, last modified January 31, 2014. http://svbj.tumblr.com/ post/75132767372/the-shadow-of-success-inside-silicon-valleys

is implemented for the interactive system in order to analyze and process qualitative, linguistic perceptual data received from occupants, and respond through modifications of color, brightness, texture and material to articulate living space as output data that is meaningful and effective.

Nadin[10] argues that aesthetic architectural design is concerned with meaning. Space becomes meaningful in its ability to successfully communicate its intended function to the user, and more so in its ability to satisfactorily accommodate intended functions—physically, psychologically and functionally. Meaning is in the architectural "expression" intended by the architect, and in the "impression" received or inferred by the observer through perceivable, identifiable properties of design elements[11]. Meaning is conveyed through definitive or implied formal and sensory expressions at various emotional, physiological, symbolic or metaphorical levels; and the observer selectively derives or infers meanings through the observer's interpretations of these expressions. The architect carefully selects and articulates forms, shapes, or sensory elements of color, light, material and texture that have perceivable, associated relations in order to express suggested meaning.

3. Concepts and Theories for Spatial Narratives

Maslow's[12] psychological model of *hierarchy of needs* in the context of architectural space design suggests that the primary goal of domestic space is to fulfill the basic psychological and physiological needs essential to survival. Pleasure is gained from architectural spaces engendered by safety and comfort as an innate survival instinct of the prehistoric hunter-gatherer human. Pleasure is a positive psychological, physiological and cognitive response that also indicates aesthetic preferences in spaces.

Several other architectural theories are linked to evolutionary psychology associated with spatial exploration stemming from the need for challenges and adventures of the prehistoric human to remain alert and active as part of survival. Psychophysiological and cognitive pleasure is derived from these architectural experiences related to theories of *mystery, risk, reward, thrill* or *peril*, as well as *familiarity* and *predictability*. These theories revolve around anticipations of aesthetic experiences of heightened pleasure—i.e., pleasant, positive experiences of reaching a satisfactory goal of a psychologically or physiologically pleasant environment, a surprising discovery that stimulates the senses, or an initial negative expectation turning into a positive experience.

In space design, a clear distinction is made between fear and pleasure in the exploration of the unknown by maintaining a level of awareness and clarity in design pertaining to perceived threat or control. Architects practice various formal and sensory spatial articulations in order to heighten the level of curiosity and encourage exploration: e.g., use of directional elements of wall curvatures, creation of visual focal points with light or color, lighting effects from dark to light, a sudden change in texture or material, partially obscured views, creation of sensory stimulating tactile or aural environments that invite engagement.

In space design, psychological, cognitive and aesthetic pleasure are derived from the complexity of textural details and contours of building surfaces, exposed structure and materials, and movement of light and shadow patterns that create stimulating, visually enhanced

[10] Nadin, Mihai (1995) Negotiating the world of Make-Believe: The Aesthetic Compass, *Real-Time Imaging*, 1:3 (August 1995): 173–190.

[11] Brandle, Kurt (2012) *Architecture and Meaning*. Michigan: Brandle Publishing, iPad edition.

[12] Maslow, Abraham H. (1943) A Theory of Human Motivation, *Psychological Review*, 50:4, 370–96. See also https://www.google.com/search?q=Maslow+hierarchy+of+need&ie=utf-8&oe=utf-8

environments.

4. Adaptability

Human activities are shaped not only by needs, but also by beliefs rooted in culture, subjective knowledge, experience, and religion. An occupant's hierarchy in living spaces changes in terms of privacy, comfort, aesthetics, values, and belief systems. Additionally, a multitude of demographical needs impacts living conditions as it becomes necessary to reconfigure living spaces. As a family grows or shrinks, needs change from an individual to a couple, from a nuclear family to an extended family, and includes occupants of different age ranges. With change of economic conditions pertaining to affordability, ownership, or tenancy, living scenarios change as well.

Flexible architecture perpetually transforms, adapts, adjusts and refines itself to accommodate the changing lifestyle and activities of the inhabitants, based on their individual, socio-economic and environmental needs[13]. It does so through spatial reconfiguration, reorganization and articulation for both physiological and psychological—i.e., emotive and aesthetic—aspects, further shaping human activity, behavior and experience. Architectural flexibility can occur at various scales, ranging from assembling or reassembling of building parts (or modules) that require a longer period of time, to adjustments of partition walls, furniture, heating or cooling systems that can be performed instantaneously.

4.1 Defining Flexible and Adaptive Spaces

In his book *Flexible: Architecture that Responds to Change*[14] Kronenburg describes the adaptive capacity of buildings to the changing needs of human and environment as an economically and ecologically viable adjustment or response reflected in a building's use or location. He typifies flexibility of living spaces according to the extent physical changes can be made in order to accommodate needs. These changes can happen in four ways and are not mutually exclusive: transformation, adaptation, mobility, and interaction.

Within the scope of this research project, *flexible* architecture broadly includes all buildings or living spaces capable of adapting to an occupant's emerging needs. The adaptation process of flexible spaces can be long-term or short-term, regardless of its frequency, and the type of interior or exterior physical changes this requires. Flexibility acknowledges "change as a design criterion. The degree of uncertainty in design pertains to demographics—i.e., family size, type, and age range—as well as social, cultural, economic, technological, and environmental factors that can be subjected to unpredictable changes. Flexible architecture makes design allowances for the various types and extents of changes that may occur in the future, making it inherently sustainable.

Adaptive is a type of flexible architecture in which the adaptation process is instantaneous or occurs within a short amount of time. In an adaptive space, space is articulated or reconfigured by means of various sensory or kinetic design elements: changeable surface color or opacity, movable screens or walls, or configurable openings. All adaptive spaces are flexible, but all flexible spaces are not adaptive. These two terms are similar in many ways, but not interchangeable.

Architecture that is *anticipatory* is flexible. In anticipatory architecture, the changes that might happen in the future are anticipated as possibilities, and spatial, structural, or technological

[13] Fox, Michael, and Miles Kemp (2009). *Interactive Architecture*. New York: Princeton Architectural Press, *ebrary*.
[14] Kronenburg, Robert (2007) *Flexible: Architecture that Responds to Change*. London: Laurence King, 2007.

provisions are made to the current state of design to accommodate possible future changes. Interactive architecture is adaptive, characterized by direct, *immediate* user-space interaction—with or without the mediation of automated sensor-actuator systems.

4.2. Adaptive Spaces: Characteristics and Principles

In the long history of flexible architecture, various adaptive capabilities have been endowed in buildings as formal, spatial, or structural characteristics, enabling them to accommodate new occupant requirements that change over time. An adaptive architectural space has two essential characteristics: provision of uncertainty in design, and active user involvement.

In adaptive living space design, the architect chooses to give up a certain level of control over design and grants the user the ability to have some input throughout the decision-making processes regarding living and behavior patterns. User participation is key, and users do not need he assistance of any specialized workforce to make formal or spatial changes.

The underlying parameter for formulating design principles in adaptive living spaces relies on how it prepares to accommodate anticipated changes. Design approaches for adaptive spaces are reductive. The inflexible architectural elements—such as structure, core, or building envelope—are simplified by reduction in number for a successful design. There are some generic principles for spatial or structural flexibility that have been used during the Modernist era and were later transferred into the contemporary scene of adaptive architecture.

Architects construct "incomplete" spaces with designated or specified functions to allow future occupants to customize them to suit their own needs. These adaptable spaces are deliberately left unfinished, to extend horizontally or vertically. Specific design suggestions are provided to motivate users to adapt in a specific manner. Architects might also provide functionally indeterminable "slack spaces" for potential expansion in the form of terraces, balconies, courtyards or storage space. Visual cues, such as beams, columns or projecting corbels, assist in transforming these spaces to accommodate various functions within a short period of time.

Spatial adaptability can be accomplished in two ways: reconfiguration and articulation. Spatial reconfiguration is formal change of space related to size and shape. Spatial articulation is the change in sensory experience of a space pertaining to its feel and appearance. Adaptive spaces generally use kinetic elements or transformable objects—e.g., partitions, doors, furniture—to change size, shape, or appearance. Dynamic forms, shapes, and functions have been developed that can adapt to technological innovations. With the invention of microchips and mobile technology, the traditional kinetic aesthetics are explored with technological innovations in contemporary adaptive spaces[15].

Spatial Articulation: With adjustment of sensory design elements, such as color, light, texture, and material properties of surfaces, an open plan can be altered in spatial quality and accommodate multiple functions without any physical changes or spatial reconfigurations. For instance, interior light or color can be altered; louvers or opacity of materials can be changed in order to create aesthetically pleasing sensory experiences and physically comfortable spaces, or to enable privacy for performing specific functions.

Building "skin" can be altered to adapt to external environment or modulate internal environment, e.g., heat, light, or air movement. With sensor-driven interactive technology, dynamic building façades interact with external environment in real time in order to control access of natural

[15] Fox, Michael, and Miles Kemp (2009), *op.cit.*

light, heat, and thermal gain and to modify internal spatial quality with aesthetically pleasing patterns of light and shadow.

Spatial Reconfiguration: Residential open plans can be subdivided by means of kinetic elements—sliding, folding or movable screens, doors and furniture—to change spatial configurations. With user participation, alteration of size and shape of spaces are constant and immediate. Kinetic elements are also used for space optimization to accommodate various activities and varying numbers of people in a single space, such as convention halls. These elements support different functions in the same space by enabling privacy, level changes, or adjustable fenestrations.

Structural Flexibility: Structural design flexibility aims to reduce the number of loadbearing walls or columns, and have clearly identifiable and separable structural layers. Open plan designs commonly use supporting structures—loadbearing columns and beams, also known as f*rame construction*—to create a large span of uninterrupted space, with a core that contains access and services. Non-loadbearing partitions or surfaces can be removed, shifted, or erected to subdivide new spaces. The *shell-core structure* is also used to create adaptive spaces, consisting of a central core with staircase, entrance, and services grouped together. The building skin surrounds a free open space for flexible use.

5. Defining Interaction in Architecture

In simple technical terms, interaction consists of an input and an output. It is the intermediary condition or the transitory state through which an action (input) generates a reaction (output). *Interaction* also suggests an exchange of information between two or more parties. Jakovich and Beilharz[16] define interaction as a “combined reciprocal action for exchanging information” between two or more related natural or artificial agents in a system, where the agent can be human, computer or building. For example, in a simple form of human-computer interaction, a single click on the mouse (input) changes the display on the computer screen (output).

In the context of architecture, interaction can be defined in similar terms. Interaction is an automatic or intuitive reciprocation of buildings to the action of the user[17]. In architecture, the artificial agent is the building or built environment, including any machine or computation technology that is integrated with architecture. Natural agents are inhabitants and environmental factors: sun direction, natural light, temperature, humidity, wind direction and speed, and weather conditions related to seasonal changes, etc. In a typical interactive architecture, interaction may occur when one agent (human or environment) performs an action or input and the opponent agent (building) generates a reaction, response, or output[18]. It is important for each participating agent to necessarily have the ability to act or respond, or both, based on the context and specificity of the information gathered from opponent agent. The nature and characteristics of interaction is restricted to or limited by the affordances of the technology that enables it.

A fundamental model of interaction is introduced by Don Norman in his book, *Design of Everyday Things*. The model describes the process of interaction that is initiated by setting a prior goal or desire by the user. Execution and evaluation are two essential actions that constitute the interaction process. The user’s initial specified action is executed in order to achieve the desired goal. Once the action (input) is executed, the user perceives and interprets the response (output) and evaluates it by comparing it to the desired goal set initially. In human-machine interaction,

[16] Jakovich, Joanne, and Kirsty Beilharz (2007) Interaction as a Medium in Architectural Design, *Leonardo* 40:4, 368–69, http://www.jstor.org/stable/20206449
[17] Kronenburg, Robert, *op. cit*.
[18] *Ibidem*.

feedforward is known as the information—cognitive, sensory, or physical—the user has prior to choosing what type of action to take. *Feedback* is the immediate result of the user's action communicated by the system through sensory perceptive means—e.g., visual, aural, and tactile. As a direct or indirect result of interaction, feedback can potentially drive further interaction. The user may choose to execute another action within the limitations and allowance of the system until the desired goal is met or a new goal is set[19].

The concept of *interaction* in architecture has its roots in the theories of Gordon Pask, a cybernetician of the 1960s who collaborated with architects and advanced his "conversation Theory"[20], which proposed that human-machine interaction should take the form of a real conversation, where both user(s) and machine (architecture) provide feedback to each other. The Paskian concept of interaction has been considered ideal by many researchers in the context of design of interactive environments[21].

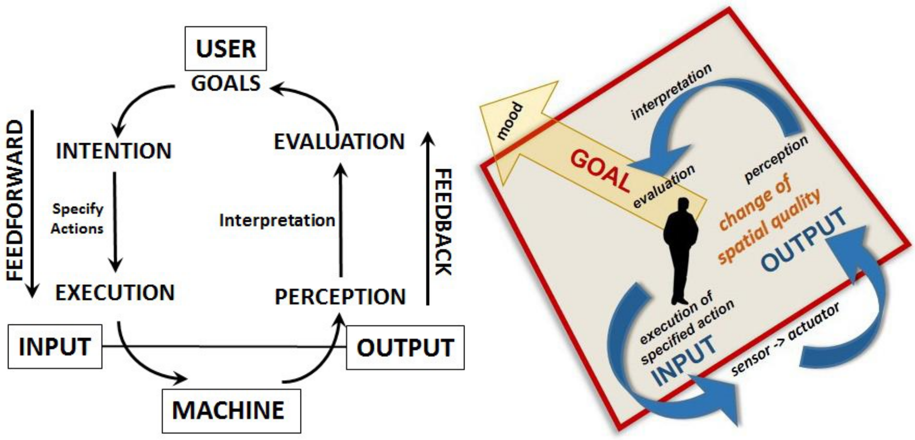

Figure 1. Don Norman's interaction model is an architectural space

Some architects discard the simple action-response definition of interaction in favor of a more complex open-ended interaction in which both parties are active participants. Based upon the Paskian concept of two-way conversation, some architects have introduced the concepts of *predictive technology* and *anticipatory architecture* in the field of interactive architecture. Michael Fox and Miles Kemp suggest that interaction should essentially be a 2-way street in which both parties are active participants.

Over the years, leading practitioners in the field of architecture and cybernetics, such as, Haque[22], Oosterhuis and Kronenburg have attempted to expand on Paskian theory of *anticipatory* systems and redefine interaction. Architect and educator Oosterhuis defines interaction similarly and proposes the development of proactive and anticipatory buildings where buildings act, respond, and change configurations in an unpredicted manner in real time[23]. The concept of Paskian anticipatory systems have been applied in his various interactive projects, such as *Moody*

[19] Norman, Dan (2013). *Design of Everyday Things*. Basic Books: New York.
[20] Fox, Michael, and Miles Kemp, *op. cit*., p. 14.
[21] Bullivant, Lucy (2007) Alice in Technoland, *Architectural Design* 77:4, 6–13.
[22] Haque, Usman. Distinguishing Concepts: Lexicons of Interactive Art and Architecture, *Architectural Design*, 2007, 77:4, 24–31; Haque, Usman. The Architectural Relevance of Gordon Pask, *Architectural Design*, 2007, 77:4, 54–61.
[23] Cf. Garcia, Mark (2007) Otherwise Engaged: New Projects in Interactive Design, *Architectural Design* 77:4, 44–53.

Mushroom Floor and *Open Burble*[24]. The automation technology of contemporary interactive architecture is being developed to implement *predictive technology* for energy efficiency.

Responsive architecture is another genre of architecture. Similar to living organisms, responsive architecture "senses" and transforms to adapt to changing circumstances[25]. This genre is based upon the idea of self-organization as a natural system, and integrates various concepts of biomimicry, autopoiesis, morphology, and hybridized environments, among other disciplines. Focusing mostly on material science and data-driven structural engineering, this genre includes parametric systems, generative designs, and concepts of "living" architecture. Responsive structures or systems generate new computation-based forms or shapes that are non-predetermined in order to withstand physical forces or weather conditions. Responsive materials, like living organisms, respond to sensations, light, or chemical actions through self-repair, self-generation or change its characteristics. These concepts, at the initial stages of research and development, are yet to be successfully adopted in the domain of habitable architecture.

6. Conceptual Living Space with Anticipatory Characteristics

In our research, the interactive living space has real-time spatial articulation capabilities driven by human-space interaction. The space articulation technique is borrowed from affective space-making methods of traditional architecture applied in interactive space design in order to create sensory-perceptive spaces. The research investigated the adaptive process of the proposed design concept, i.e., how it anticipates in order to achieving design goals. Design provides anticipatory affordances in its current state by taking into account the prior and possible future actions of occupants. The living space adapts to emergent user needs by enabling the occupant the ability to search for possible spatial solutions in order to meet his/her current and future needs, desires and actions that have not yet been realized.

The adaptive process of living space explores anticipatory dimensions from multiple perspectives:

1) inception of design idea established on known and predicted needs and requirements of target occupants;
2) the formulation of the design criteria and provision of anticipatory design affordances to meet design goals; and
3) an occupant's aesthetic and creative exploration of an temporary, dynamically evolving domestic space of undetermined function.

6.1. Design of an Adaptive, Minimalist Action-Space

At the core of any architectural design is the concept or idea of function and activity patterns the space intends to shelter, from which the forms and structure of the space generate[26]. Architecture is anticipatory in its initial stages of concepts, schematic drawings and model scenarios that are produced as abstract representations of possible actions and interactions that may occur in future[27]. These future states of possibilities are derived from establishing known and perceived

[24] Haque, Usman. The Architectural Relevance of Gordon Pask, *Architectural Design*, 2007, 77:4, 54–61.
[25] Beesley, Philip, Sachiko Hirosue, and Jim Ruxton (2006). "Toward responsive Architecture. In: (Beesley, P. et al, Eds) *Responsive Architectures: Subtle Technologies*, 3 –11. Toronto: Riverside Architectural Press.
[26] Alavi, Hamed S., et al. (2016) Interaction and Architecture: Deconstructing Human-Building Interaction, *Interactions* 23:6 (November-December 2016), 60–62.
[27] Zamenopoulos, Theodore and Katerina Alexiou (2007) Towards an Anticipatory View of Design, *Design Studies* 28: 4 (July 2007), 411–436.

needs, desires and expectations that impact the current state[28]. Occupant narrative drives the explicit and implicit program (function) designed for an architectural space[29]. This narrative is based on an occupant's needs, expectations, and desires for his/her living space that the space must provide for. Understanding the occupant's narrative is essential to designing the spatial narrative or *action-space* that supports current actions and possible future actions**.** *Action-space* is defined by the everyday actions and activity patterns predicted or expected to take place, as well as the interactions, not only between people, but also between complex human behavior and available technology, that are redefining conventional use of domestic space[30]. This complex interaction with technology satisfies the need to accommodate multiple, overlapping activities in a single space, such as reading, working, web browsing, watching TV, listening to music, socializing, dining and resting. Technological advances promote minimalism in lifestyles, allowing the domestic and the professional to overlap.

Design criteria are formed based upon the study of *action-space* for target occupants. To derive the configuration of *action-space* for neo-nomads—size, shape, usage patterns, environmental and spatial flexibility of space—their demographic data and lifestyles are examined in order to anticipate potential use of technology, as well as future possible actions and interactions that may take place in their living environment. The neo-nomadic lifestyle has been studied through observation, literature, and subjective personal experiences pertaining to individual, socio-cultural, economic and technological aspects.

Study reveals that neo-nomads "live light" in terms of personal belongings and space requirements. Their minimalist living is characterized by multi-functionality and optimization of space. The boundaries of *action-spaces* for their daily living activities are blurred. The proposed neo-nomadic living space must embody space optimization and spatial flexibility in the form of a use-neutral living space that adapts to the constant transitional and temporal shifting from living to working, personal to social, and physical to digital. Spatial solutions must extend beyond the conventional multi-purpose furniture design of compact living into the architectural realm of space-making.

One criterion is to design an adaptable living space that can change in spatial quality, i.e., feel and appearance, according to the user's needs. Spatial solution is sought in the creative realm of affective, experiential space design that transcends the strict physical boundaries of size and shape. Affective space creation of traditional architecture with variables of space perception—color, texture and materiality—is introduced as a means of spatial transformation in which visually perceivable sensorial spaces intend to accommodate an occupant's multiplicity of possible functions at conceptual, psychological, physiological, creative and aesthetic levels. As activity depends on context—prevailing mood, emotions, spatial setting or atmosphere—the intention of performing an activity and efficiency of performance rely on physiological and emotional comfort triggered by perceived psychophysiological and aesthetic spatial qualities.

Another design criterion is to grant the occupant the ability to customize and personalize space according to his/her desire through modification of affective spatial qualities in order to carry out desired functions. The ability to personalize space is key for occupants residing in a

[28] Nadin, Mihai (1999) Anticipation: A Spooky Computation, *International Journal of Computing Anticipatory Systems, Proceedings of CASYS* 9:6 (CHAOS: Liege, Belgium, 1999), 3–47.
[29] Lehman, Maria L. (2016) *Adaptive Sensory Environments: An Introduction*. London: Routledge.
[30] Kirsh, David (2001) Changing the Rules: Architecture in the New Millennium, *Convergence: The Journal of Research into New Media Technologies* 7:2, 113–125.

dematerialized context. Abbas explains the manner in which mobile professionals search for an identity in order to inhabit a place of transit, such as, a hotel room, through the creation of personal associations to objects, ambience, or artifacts that make them feel “at home”[31]. This feeling pertains primarily to feelings of comfort, security or having the ability to personalize and customize in search of an association. To inhabit a space, one seeks a connection to memories of events, environments or objects in order to establish a notion of propriety or a personal territory that is beyond the physical[32]. Home is found in the openness, enclosure, warmth, lightness, or darkness of “fragments of spaces” conjured memories of past domestic habitats filled with emotions and feelings of security, safety, intimacy or solitude[33]. Personalization through light or color to create the appropriate mood or ambience may be sufficient for grounding one in a physical environment as a place to inhabit.

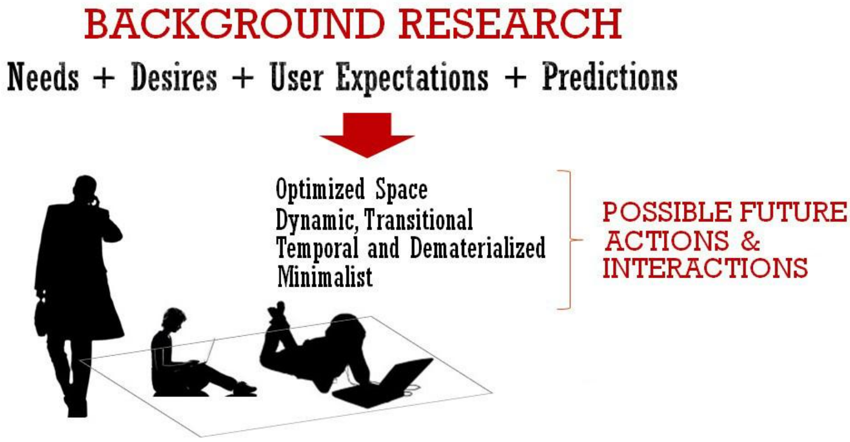

Figure 2. Background research to formulate design criteria

6.2. Enabling Anticipatory Capacity

Based on design criteria, certain features are integrated in design to ascribe to it the anticipatory capacity to achieve its goals. The first design feature is the integration of interactive technology. The interactive surfaces of the living space have the ability to change appearance by means of modification of the design parameters of color, brightness, texture, and material in response to occupant input. A second design feature is the application of space articulation techniques intended to transform spatial quality in a visually expressive, sensory-perceptive way through modification of the design parameters. Design acknowledges the strong impact of color, texture, and materiality as space-making elements on human moods and emotions. The space articulation technique is integrated in the interactive medium in which modification of design parameters can potentially create various spatial qualities that are meaningful to the occupants. The

[31] Abbas, Yasmine (2006) Neo-nomads: Designing Environments for Living in the Age of Mental, Physical and Digital Mobilities (PhD diss., Harvard University, Cambridge s MA), p. 92.
[32] *Ibidem*.
[33] Bachelard, Gaston (1994) *The Poetics of Space.* Boston: Beacon Press.

process of meaningful space creation with the application of space articulation techniques is based on the formulation of design guidelines.

Interactive technology and space articulation technique are the two components of design establish the backdrop for an adaptive, spatio-temporal living space based on human activity, mood, and emotion. They set a stage in which the occupant expects possible psychological scenarios to emerge through active sensory engagement and interaction with space. Design assumes interactive technology to trigger human-space interaction in order to articulate space in real time and produce a set of spatial possibilities for achieving the design goal of accommodating the lifestyle of young professionals.

The human-space interaction in this design is between human and machine, between occupant and the living space. Each deliberate action or input of an occupant is reciprocated with a response or output from the living space controlled by the embedded interactive system. The occupant's input pertains to his/her desirable affective qualities of space to satisfy needs. It is the emotional response to perceived affective qualities of living space, such as degree of warmth or coolness, spaciousness or intimacy. The output of living space is in the form of modified or articulated sensorial spatial quality as spatial feedback through manipulation of surface attributes of color, brightness, texture, and material (see Fig. 3).

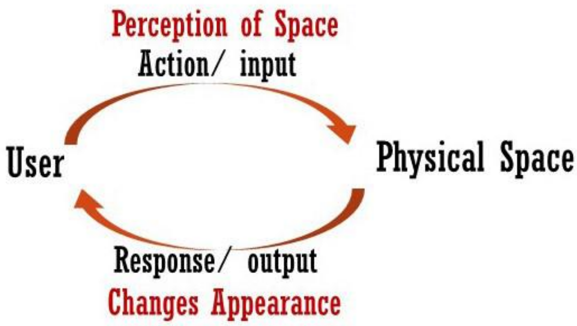

Figure 3. Human-Space Interaction of Living Space

6.3. Creative and Aesthetic Goals

Anticipation of possibilities in spatial feedback is essential for continual interaction with space. Perception and interpretation of each spatial feedback is informed by prior spatial experience that can inspire new sets of anticipation as well as formulation of new spatial goals never conceived before by the occupant. The subjective perception and interpretation of space relies on context: memory, imagination, thoughts, culture, as well as prevailing mood and emotional states. As mood influences how space is experienced and interpreted, the experienced space also has an impact on prevailing mood and emotions. The anticipatory element of interaction is thus contextual and non-predetermined at feed-forward. Through formulation of new spatial goals, the occupants exploration of experiential space-making may extend into creative realms beyond satisfaction of basic psychophysiological needs.

In anticipatory design, imagined ends drive creative and aesthetic processes with underlying anticipations of possible outcomes[34]. An occupant's creative exploration of space-making imagines

[34] Nadin, Mihai (2010). Anticipation and the Artificial: Aesthetics, Ethics, and Synthetic Life, *AI & Society* 25:1 (April 2010): 103–118, doi:10.1007/s00146-009-0243-0

goals of possible psychological scenarios. Similar to the theatrical *mise-en-scène*, living space transforms into scene renditions, setting the stage for specific actions to take place, with sensory design elements for visual storytelling. In this process, generated spatial experiences can have infinite variations in which each sensation is unique and personal.

The occupant's action and behavior are influenced not only by spatial context, but also by the abilities to interact and modify spatial experiences in real time. Fleischmann and Strauss[35] discuss the phenomenon of the "active participant" in which the observer's role reverses as he/she actively engages with the "identity-giving machines" of interactive media art and design. Interaction converts ideas into immediate actions, forging unique relationships with machines and objects and endowing new meanings[36]. As an active participant, the occupant is engaged in a continuous dialogue with the living space, facilitated by experiential space-making and its influence on the perceptual process of space. This interaction adds a unique dimension to the role of architectural space influencing human behavior.

7. Future Work

Explorations of affective dimensions of space can further include a variety of affective dimensions that are desired in a real-world domestic habitat. These include, but are not limited to: feelings of security, contemplation, spirituality and creativity. Construction of these mood- related ambiences are intended for accommodation of specific functions. To realize such spaces, spatial imageries with symbolic meanings and cultural and temporal meanings of color, light and material should be explored in order to provide such imaginative dimensions to perceived space Future research also includes introduction of simulated natural light as a key sensory design element, and its various psychophysiological, metaphysical and symbolic dimensions need to be explored. Natural light has significant impact on feelings of spaciousness—a spatial aspect that needs further exploration for tiny, shared living spaces for young professionals. Design with natural light also relates to temporality. Abstract representations of modulated light and shadow, material and color on interior surfaces can reflect external weather conditions, and real-time diurnal and seasonal changes to perceptually situate occupant within the external world.

The future of nanotechnology-driven smart materials offers new possibilities for interactive architecture. Properties of smart materials change under the influence of force, magnetic or electric fields, chemical reactions, light, temperature or humidity. Some materials interact with external stimuli and change in color, pattern or behavior. Thermo-responsive and shape-memory alloys that respond to light or touch have been explored in "responsive" art installations[37]. Extreme performance "smart" materials, although deceptively thin and light-weight, are able to carry heavy load[38]. Research and development of nanotechnology-driven smart materials may bring new possibilities in the development of interactive spaces. These materials may have unique characteristics with the capacity to modify color, texture, reflection or transparency in response to human interaction.

Future work may involve research on the adaptive process of interactive space integrated with "learning." The idea of integration of data and learning has been explored in various visual

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35 Fleischmann, Monika, Wolfgang Strauss (2008) Interactivity as Media Reflection between Art and Science. In: Sommerer, C. et al, Eds) *The Art and Science of Interface and Interaction Design*, 75–92. Berlin/Heidelberg: Springer, p.78.

36 *Op.cit*.

37 Beesley, Philip, Sachiko Hirosue, and Jim Ruxton, *op.cit*.

38 Yirka, Bob (2015) Boeing Demonstrates Lightest Metal Ever, *Phys.org*., October 15, 2015, https://phys.org/news/2015-10-boeing-lightest-metal.html

fields of graphics gaming and clothing design[39]. In this process, architectural space "learns" to solve real-world complex problems related to decision-making that involves mimicking human thinking. Architectural space can gather data over time and "learn" through trial and error in order to improve its capacity to make suitable spatial decisions or possibilities for its occupants. For an interactive space that is meaning-driven, learning involves various disciplines related to architectural design methods, sensory perceptual process and cognitive thin king that impact and condition emotion and behavior, and subconscious behavior, together with occupant's subjective personal taste, preferences, daily routine, lifestyle and habits. Knowledge from other disciplines, e.g., psychology, neuroscience, and nanotechnology, can be integrated as part of the learning process. Over time, interactive space will train itself to articulate spaces tailored to user goals and needs representing occupant's reality—i.e., identity, beliefs, culture, traditions and values.

In this research, space perception was limited to the visual field. Future work may extend into the multisensory dimension of space perception, especially into the auditory domain. Manipulation of sound as an essential part of human ability for perceiving surrounding spatial volumes and its impact on psychophysiological, aesthetic and metaphysical spatial dimensions can also be further explored as a design concept for neo-nomadic living spaces.

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77:4, 54–61
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