Environmental design studies on perception and simulation: an urban design approach

Les études sur la perception et la simulation en design environnemental : une approche par le design urbain

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Introduction: experiential simulation and urban design

Aim, methodology and field of application of the work

1   Working on perceptual urban simulation requires to investigate the complex relationship between man and the environment and consequently between man and simulation. The discrepancy occurring between reality and simulation and the technical components that help narrow these two dimensions represent crucial topics for understanding the limits and opportunities of perceptual and experiential simulation. At the same time the construction of a theoretical framework on simulation starting from the studies on cognitive perception, legitimates the implementation of novel tools. In fact, without a serious investigation on the mechanisms of perception and cognition, there would be no meaning in undertaking complex works on simulation. For instance, many questions arise concerning what we perceive in reality, what are the filters occurring between man and his or her environment, what are the implications of subjectivity in the understanding of the physical world and the construction of a collective imagery, and finally how we can faithfully give back the complexity of the world within simulation.

2   The aim of this work is twofold: firstly, we want to give back an overview on the relevance and applicability of the topic of perceptual simulation within the urban design discipline through the reconstruction of a selected set of references and definitions; secondly, the explored literature and the experimental research were used in order to

implement a set of tools and applications for design. Hence, depicting a comprehensive framework helped us in structuring all the issues related to the simulation of reality (reliability of the images, of the observer's conditions, etc.); following this, we propose a conceptual framework that includes a matrix of tools, serving as the pieces of a mosaic to guide towards an informed approach and application to simulation for urban design. In fact, we argue that the novelty of the paper relies on the proposal of the systematization of the framework, which enabled us to generate the 'matrix of simulation tools' as presented in the last section of the paper. In so doing, we would like to achieve a comprehensive overview on the link between perceptual experience and simulation in general. According to Donald Appleyard (1977), we share the idea that a mixed use of tools and techniques helps in overcoming the different limits given by the single types of simulation for a more comprehensive understanding of the environment. We started investigating perceptual simulation by mainly addressing the visual component, but the same approach is adaptable and desirable for the other sensory dimensions as well.

The mission of urban design

3   In particular, our focus is mainly on environmental urban design, intended as a specific dimension of design that involves the understanding of the built environment and its relationship to man, essentially exploring how space affects the wellbeing of people. Other forms of design, like interior design, architectural design and urban planning might benefit as well from the use of the proposed tools, as long as these are finalized to the design of the man/environment relationship. Moreover, several other disciplines deal with environmental studies from different perspectives, among others: environmental geography, sociology, and psychology. Interdisciplinarity among environmental studies should be fostered in order to integrate the same approach to different aspects.

4   Hence, investigating the way we perceive and make use of the physical space is a crucial task for informing design and producing accurate simulations; this sensitivity towards the consciousness of the environment should be at the very basis of the designers' toolkit, but unfortunately, it is not always the case.

5   Traditionally, human beings direct their efforts to improve quality of life, mainly acting on the environment they inhabit: for instance, humanities, science and technology, are finalized to improve the welfare and the wellbeing of individuals and the society. The discipline of urban design has the same aim, and this is even more evident because it deals with the transformation of the physical space we live in. Within this discipline, a series of devices have been implemented to improve the built environment have been implemented and continuously sophisticated over time. The question about how to realistically anticipate and verify the effect of design outcomes on everyday life of people in time and space, is one of the major tasks of urban design, and for sure the most challenging one for scholars working on representation and simulation. We argue that experiential simulation can be one answer to that challenge, if intended as a technical device to accurately mimic places and their atmosphere. In other words, the mission of efficiently depicting the physical world (through simulation) is legitimated by the intention of improving the real world itself. Nevertheless, the complexity of this operation requires a deep understanding of the mechanisms of perception happening within the ecologic system that correlates man and environment, as tentatively interpreted and introduced later in the text.

Introduction on the use of simulation in design and arising issues

6   Architectural and urban design do not systematically make use of realistic prototypes as industrial design does in order to test outcomes. Despite that, in research and professional work, simulation is used in many ways and with different scopes. In particular, "perceptual simulation attempts to provide tangible, concrete replicas or isomorphs of environments - often future environments - that can be displayed to observers for their evaluation or other response" (McKechnie, 1977, p.174). Beside perceptual simulation, scholars also refer to experiential or realistic simulation; in this paper, we make use of the term experiential because we would like to stress the engaging dimension of mimicking the atmosphere of places. This field was re-launched by the rapid advancement of ICT. The attempt of giving back the complexity and the derived experience of the physical world opens up many issues, especially in urban and landscape design; in particular: the acceptance of simulation by designers, the implications on design thinking and the reliability of the products and the level of accuracy.

7   There are two main reasons why designers could reject the use of simulation: firstly, experienced designers could argue that they have a clear idea of the visual mental imagery and the complexity of envisioned future places (Kavakli and Gero, 2001). Hence, they do not need sophisticated tools for representing the outcomes of design schemes (according to the principles of efficiency and economy of their work); secondly, in order to give back the atmosphere of places, they could prefer to extract the significant features of their design schemes through more synthetic forms of representation (thus making use of the expressivity of visual representation) which gives back the atmosphere they have in mind through their *poiesis*. Nevertheless, we argue that designers also have an obligation to society – at least to the clients – in communicating an idea to laymen which is already clear in their minds. Moreover, simulation offers a solid way for validating design outcomes in time and space, and designers could benefit from this, because they could evaluate the cumulative interaction of different design choices and the emerging dynamic implications.

8   Simulation does not only represent a validation method to assess and anticipate design outcomes. It radically changes the way of thinking and doing design. A greater attention to the experiential and physical aspects of design is a direct consequence of an approach that takes into account human perception of space, thus placing people at the centre of attention. In short, we argue that the correct use of perceptual simulation helps in placing a greater focus on the intangible outcomes (relationship man/environment and wellbeing), rather than the physical architectural object *per se*. Simulation can support design in an heuristic manner, by enabling a continuous process of 'learning by doing', 'trial and error' and 'generate and test' (Schön, 1983; Rowe, 1987) for the validation and improvement of solutions, thus enabling to better manage complexity in architecture and urban planning.

9   The ease of producing photo-realistic visualizations represents an advantage for research, but also a risk of bias in the understanding of representations, if simulation is used in a misleading way, for example only for commercial purposes (Appleyard, 1977). This is the reason why Stephen R.J. Sheppard (1989, 2001, 2005) invokes an ethic for visualizations. Hence, we argue that a deep theoretical understanding about the sense and potential uses – but also risks of biases – of simulation in design is crucial when we

define the mission and scope of different modalities for anticipating future environments. The issue of validity will be addressed later in the text.

10 Hence, the more intuitive, interactive, immediate and responsive the simulation tool is, the greater the benefits to practice. In the attempt of refining the efficiency and validity of experiential simulation techniques, different features can be implemented. In particular, we think that three aspects are crucial: *immersivity*, *interactivity* and *multi-sensoriality*. These features encourage engagement and dynamic personal experience that contribute to personal understanding of the simulated scene. Nevertheless, in this process of continuous refinement of experience brought into simulation, are we giving back reliable information? For instance, are we giving the proper relevance to each element thus achieving the correct balance among all the features of the depicted environment? Since simulation is necessarily a simplification of the depicted environment, how can we define an acceptable gap between reality and multi-sensory simulation in order to achieve unbiased subjective perception? How can we do that, if we perfectly know that perception is a totally subjective operation whereby each person reacts to sensory stimuli in different ways? How can simulation take into account this complexity?

The content of the article

11 All these questions are at the basis of the content presented in the article. In the next section we aim at reconstructing a schematic process about how we make use of the mechanism of perception within the man/environment eco-system, where simulation occurs, and how it tries to replace the experience of the physical world for urban design purposes. In doing this, we do not have any ambition of introducing a new theory on perception of the world, but rather we refer to existing theories relevant for the design discipline in order to provide a conceptual framework for our experimental work on experiential simulation. In particular, we want to clarify where simulation plays a role in the conceptual process of design, what is its relationship to the physical environment, and where the emergence of the concept of the *ambiance* of places comes up in the perceptual process between man and environment. Afterwards, a specific focus on simulation and its application to urban design clarifies our critical approach to the topic in the research and design practice with a specific focus on the validity of the products. Finally, the last section introduces a series of tools and applications derived from the reconstructed exploratory framework in order to give to the reader effective feedback about the usability of simulation tools in practice.

The conceptual framework: the man/environment relationship, experience, urban design and simulation

12 This section aims at reconstructing the authors' interpretation of the mechanisms of perception as an essential step for assigning to simulation the proper role and meaning within the design process. In order to achieve a clearer and coherent picture of the mechanisms of perception and simulation, we organized our arguments on the basis of a number of schemes that attempt to reconstruct and describe the man/simulated environment relationship. Once again, we underline that we do not have any ambition in displaying a theory on perception, but we use this interpretation just for getting an

understanding about what is simulation to us, which are the relevant elements to take into account while producing a simulation, and at which stage of the design process experiential simulation plays a role.

The state of the art

13   Most of the following interpretation of perception and design originates from an elaboration of previous studies, that we cannot avoid to mention, even if only shortly for the sake of brevity. In particular, urban design explorations are very broad and touch other disciplines. Hence, a global picture of references is hard to trace, even if the framework outlined by Anne Vernez Moudon (1992) still remains a beacon for the categorization of urban design research dimensions: image studies, environment-behaviour studies and place studies are the areas of concentration that include most of the authors encountered in our research and introduced in this article. The first reference to perception in landscape design is Humphrey Repton's Red Books (Repton & Malins, 1976), while in urban design is Camillo Sitte's work (2002, first edition 1889), which introduces most of the issues related to experience occurring in the built environment. Sitte could not benefit from the advancement of studies on cognitive and ecological perception (Kosslyn, 1980; Gibson 1986) and Edward T. Hall's introduction to *proxemics* and the investigation of social distances (1992, first edition 1966) that opened up a number of explorations in design. We mostly refer to the work by Kevin Lynch (1960), Gordon Cullen (1962), the Berkeley school during the 1970-80s (Appleyard et al, 1964; Appleyard, 1977; Craik and Zube, 1976; McKechnie, 1977; Sheppard, 1989; Bosselmann, 1998, 2008) and American authors in general (Arnheim, 1977; Tuan, 1977; Stokols, 1977; Altman et al, 1980; Thiel, 1997; Whyte, 1980). A translation of the topics to the design practice was attempted with success by a number of European scholars like Steen E. Rasmussen (1959), Jan Gehl (2011, first edition 1971; Gehl & Gemzøe 2004, first edition 1996), Juhani Pallasmaa (1996).

14   In environmental psychology, research investigated the reaction of people to the perceived world by considering the mechanisms behind the process of cognition and the consequent construction of the personal judgment; in particular, Stephen Kaplan (1979) explored the evaluation of 2-D versus 3-D scenes through four informational elements, namely: coherence, complexity, legibility and mystery.

15   With the advancement of technology and the emergence of digital modelling and virtual reality techniques, introducing dynamic aspects into simulation becomes reality. Hence, a new set of research questions, contributions and applications in the field of urban and landscape design emerged (among others, we mention Mach & Petschek, 2007). For instance, Bishop and Lange (2005) gave a theoretical and applied insight on the use of virtual environments and simulations for design, in particular landscape design. Moreover, the Ambiances network is specifically exploring experiential and sensory themes in space and time (see for instance Thibaud, 2011; Thibaud & Siret, 2012). More references to recent research are introduced later in the text.

The man/environment relationship

Illustration 1: Physical world and perceived world
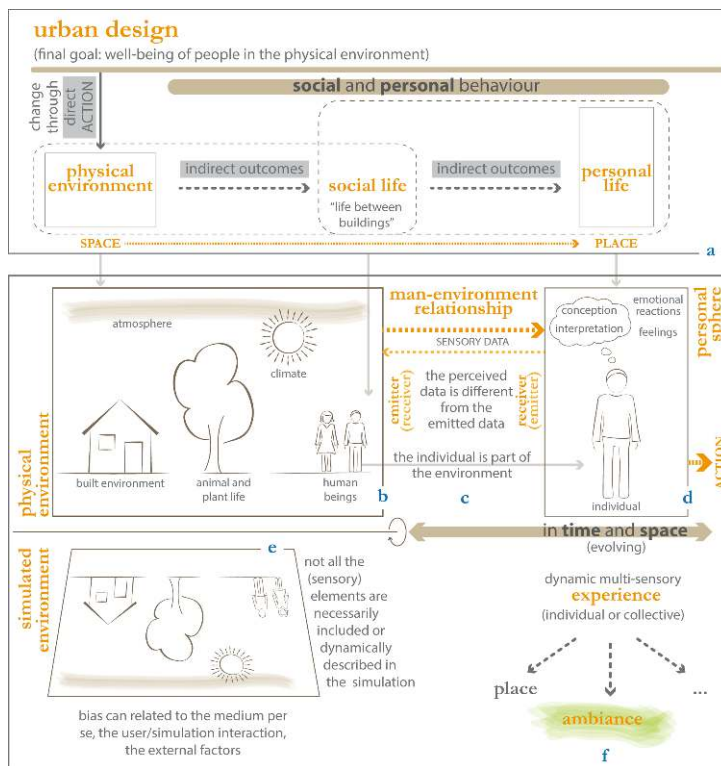
(A) THE DOMAIN OF URBAN DESIGN. (B) THE REAL ENVIRONMENT. (C) MAN, ENVIRONMENT AND THE MUTUAL RELATIONSHIP. (D) MAN. (B, C, D, E AND F) ARE RECALLED IN ILLUSTRATION 3 IN TEMPORAL DYNAMIC TERMS.

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16   The first statement we want to start with is that we never perceive reality as it is. Even if we can conceive an outer reality, we can only experience it through the interaction of our body and mind, a process that involves the actions of *sensing, perceiving, experiencing* and *knowing*. This argument alone is essential to justify all the reasoning we introduce below on cognitive perception and the resulting complexity that we have to face when we try to define what the process of perceptual simulation is, and what is its object indeed. In particular, Illustration 1 gives back a very general and comprehensive overview in order to establish a tentative relationship occurring between man, environment, the human perception of the physical environment, the resulting perceived world, and the role of the discipline of urban design and simulation. The illustration will support the description we provide in the following text.

The domain of urban design

17   We argue that personal and social behaviours happen and develop in the physical space, and space and people have mutual influence expressed through culture. Hence, the role of the physical design of space is crucial, even if it is not the only component that determines the quality of space and the wellbeing of people. The upper part of Illustration 1a refers to the design dimension. For instance, when we design or evaluate spaces we aim at satisfying human needs, and we are necessarily conditioned by our cultural and personal inclination and interpretation of the concept of wellbeing (Hall,

1992, first edition 1966). Thus, the outcomes of urban design should not be judged *per se* (as an objective reality), but rather evaluated in relationship to users (Rapoport, 1980). In fact, urban design directly affects the physical environment and indirectly everyday life of people (experience) and thus social and personal behaviour in a recursive way. In other words, the construction of the material space enables – or, on the contrary, it can impede – to activate human dynamics thus creating social life, what Jan Gehl calls *life between buildings* (2011, first edition 1971). Finally, within this social space, the personal life of individuals occurs.

Sensing, perceiving, experiencing and knowing

18   Let us start with the central part of the scheme where we represent the real environment on the left (Illustration 1b) and man on the right (Illustration 1d). On the left part (Illustration 1b), we are simply referring to the materiality of the physical world (it is not our intention to bring into our schematization philosophical thoughts on the question about what is reality indeed). The basic assumption is that the world around us has to be filtered by our senses (Illustration 1c). In a simplified interpretation of the process, the environment is seen here as the main emitter and the individual is the main receiver of stimuli, following the traditional communication model (Shannon & Weaver, 1949, recalled in Lange, 2005 in relation to 3-D visualizations; Berlo, 1960). The individual catches incoming data through sensory receptors, and this is the key passage to introduce the topic of the subjective experience. If we consider the emitted data *per se* we are in the realm of the objective world, while if we see the same data from the point of view of a person, then we enter into the subjective sphere: once experienced, 'space' becomes 'place'. In this transition, the receiver moves from *sensory perception* (nerve impulse) to *cognitive perception* (conception, interpretation, experience, and thus knowledge), where the individual processes the impulse giving to it meaning and significance, from the outer world to the inner one (concerning the visual cognitive process we mention: Kosslyn, 1980; Yuille & Ullman, 1990; Biederman, 1990). Of course, the processes of perception and cognition are never linear, and we are not only neutral passive receivers of external stimuli; in fact, our brain highly affects the way we perceive, so that the two acts of perception and cognition are hard to separate and perception is an active process (Arnheim 1969). For instance, since each individual is unique, it is not surprising that the correspondence between outer reality (objective – physical world) and the inner one (subjective – perceived world) is not one-to-one (Thiel, 1997). Even if we have a shared idea and understanding of things, several personal realities can correspond to a unique physical reality, at least one per person. In fact, the objective data, e.g. temperature, can be different from the perceived one: in a given space, one subject can feel cold and another one not. Nevertheless, some common trends are generally recognizable, and looking at things from a distance allows us to generalize some perceived conditions: for instance, we know that a room would be generally perceived as comfortable when its temperature lies between 20 and 22 Celsius degrees, even if someone could still feel cold or hot in it.

## The physical versus the perceived environment

19   Therefore, in order to assess the final quality of a human environment we have to shift our attention to the relationship that links the physical environment and the people who

live in it (Illustration 1c). This means that we have to focus attention on the *affordances* in space and time (Gibson, 1986). To do that, we have to define the man/environment relationship (eco-system) thus focusing on the characteristics that influence their interconnections. Obviously, we need to provide a simplification of this complex process, i.e. a schematization that is far from being exhaustive, but can nevertheless be useful to address and to argument on the necessity to reinforce this approach both in education and professional practice.

20   Going back to our understanding of the physical world (Illustration 1b), we try to depict the main features that describe it. For instance, if we want to organize the physical world *per se* in its principal components, we can roughly reduce it to four main elements: human beings, non-human beings (i.e. living beings like plant and animal life), built environment, and climate. As introduced above, the built environment - and to some extents landscape - is the realm of designers if intended as a man-made artefact. The interaction and mutual influence of the above mentioned components (including people as part of the environment) generates the *eco-system* and, together, the *atmosphere* of a place. In fact, we define the atmosphere as the complex interaction of the physical features of the environment that contribute in creating the peculiar physical identity of space. For instance, the material properties of a space (quality of the soil, presence of water, and so on) together with climate conditions enable the generation of specific lifestyles, behaviours and natural settings (eco-system). All these features cannot be disjointed and result in the uniqueness of physical space (atmosphere). In short, atmosphere is not just something added to space, but is a more comprehensive and complex result of the interaction of the environmental features. Consequently, the *ambiance* of a place is here intended as the physical atmosphere processed through human senses, culture and personal experience (Illustration 1f and Illustration 2) (Rapoport, 1993). In other words, the environment emits sensory data, received and processed by individuals, and within this process, we recreate our personal understanding and give values to the environment (thus deriving the ambiance of places); this is what Jack L. Nasar (1998) calls the evaluative response, which "arises from the person, the environment, and the interaction between the two" (Nasar, 1980, p. 30). Hence, the definition of ambiance differs from atmosphere, because it brings in the human personal perspective and narrative of a place. Design – especially urban and landscape design – gives high value to *place making*, as one of the main targets of the discipline: respecting places, enhancing or rediscovering the ambiance of places are the very essential actions and ultimate goals of design.

Illustration 2: Physical versus perceived environment

PHYSICAL ENVIRONMENT ←⋮→ PERCEIVED ENVIRONMENT

space ←⋮→ place

atmosphere ←⋮→ ambiance

sensing
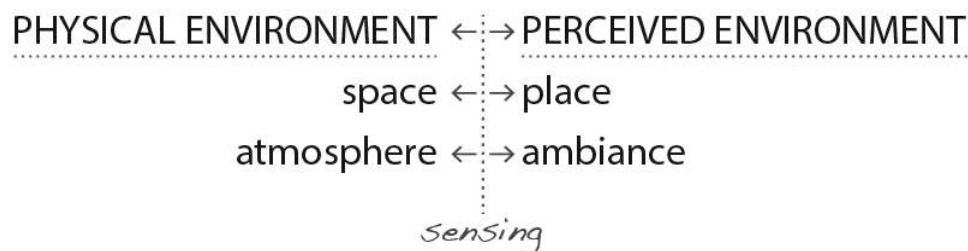
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Experience in time and space

21   The subjective perspective occurring in time and space generates the experience (Illustration 1f and Illustration 3). According to Yi-Fu Tuan "Experience is a cover-all term for the various modes through which a person knows and constructs a reality. These modes range from the more direct and passive senses of smell, taste, and touch, to active visual perception and the indirect mode of symbolization. (...) To experience is to learn" (1977, p. 8-9). Hence, personal experience leads people to develop their own awareness and meaning of a place. This process contributes to shape our emotions and feelings: from place to the sense of place. We argue here that the shaping of our personal experience is the result of multiple and interacting factors affecting both the perceiver and the physical space.

22   In short, the living experience is informed by time and space: in fact, perception occurs in the present time and is conditioned by past experience and contributes to drive our future actions (Illustration 3). This introduces the concept of relativity and hence the dynamic relationship emerging between the perceiver and the outer world.

Illustration 3: Environment and perception in time and space
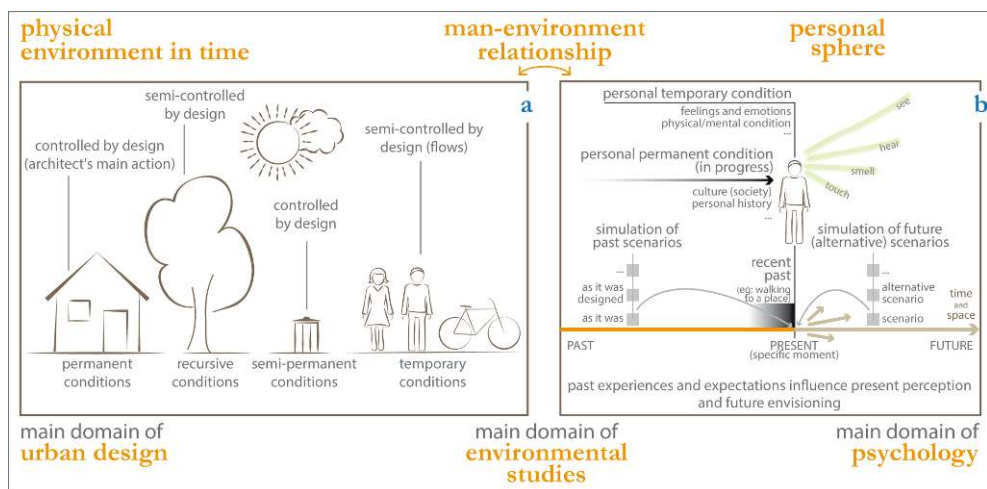
(A) THE PHYSICAL ENVIRONMENT. (B) THE PERSONAL SPHERE.
SOURCE AND COPYRIGHT: THE AUTHORS

Multisensory experience

23   Environmental features are perceived through sensory data, which have different characteristics and collaboratively contribute to spatial comprehension. Multisensory experience is crucial in evaluating the characteristics of different simulation tools. Moreover, as argued by James J. Gibson (1986), perception is never a static process, but happens in the physical world and in time through the movement of the body.

24   The acts of sensing and cognition, hence, are very complex phenomena that concur to shape our mental images of places and their ambiances: we receive a complex system of data through our system of senses. First of all, sight and hearing behave as distant receptors (Hall, 1992, first edition 1966). Sight is the sense that allows to project ourselves

farthermost: for instance, in the plain we can see the mountains kilometers away, even if we cannot catch details; normally, we look in the direction of our motion, but we also visually scan the world around us to locate ourselves in space and understand the surrounding environment (Danahy, 2001). On the contrary, the sense of hearing is mainly omnidirectional; we can perceive sounds coming from behind, and even beyond a visual barrier. In general, we are also able to understand the location of the sound source around us, and this can contribute to guide our motion in space; we can also suggest the distance (at least near or faraway) and, based on the Doppler Effect, the possible direction of the motion of the sound source. For instance, we can decide to turn the corner because we would like to see the hidden fountain previously perceived through the water soundscape only. Even if hearing allows us to perceive elements hidden to sight, its range of action is more limited than the visual one and depends on the intensity of the sound source. The sense of smell is spatially even more restricted than the previous ones, but when an odour is persistent and diffused in a place it really identifies it in a strong way; typically, street food connotes several public places around the world. Touch is the sense with the shortest range of action, but this does not mean that it is less important; temperature, which greatly contributes to our feeling of comfort, is felt by this sense through the skin. Some instinctive actions, such as getting off the sidewalk, are informed by a change in the roughness of the pavement that also recalls our attention. In general, the spatial presence or predominance of sensory features in space contributes to mark the place itself: commonly, the more present and significant the data is, the more it is associated with the place and what we experience there. In so doing, it contributes to define its ambiance. Beyond the five senses researchers do not agree on the number of senses typically involved in the perception of the environment; in any case, at least two other systems contribute to define the experience: the kinaesthetic (sense of motion) and the vestibular system (sense of balance) (Lange, 2005).

25 In fact, during the dynamic process of spatial navigation, which contributes to spatial cognition, the subject can use two parallel interacting *spatial reference frames*: the self-centred *egocentric* one and the environment-centred *allocentric* one (Burgess, 2006; Plank et al, 2010; Roupé & Gustafsson, 2013). In the first case, the subject is the reference system, and thus the origin of the axis (front-back, right-left, and up-down), hence distance and bearing are inferred according to the self-position only; in the second case, instead, the environment acts as the global reference, where the subject is located without any orientation, since allocentric distances and bearings do not change: the navigator has to update position in relation to the general layout (Plank et al, 2010). Even if the two systems generally collaborate, it is possible to distinguish between *turners,* i.e. subjects that prefer to refer to the egocentric frame, and *nonturners,* i.e. the ones that favour the allocentric one; moreover, other reference frames are used in combination, such as the eye-, body-; head- ones (Plank et al, 2010). In this cognitive process the subject associates objects to known ones, and in doing this he or she identifies, categorizes and classifies them (long term memory in Illustration 3b) (Roupé & Gustafsson, 2013); finally, in this process current perception is also influenced by previous short term perception (short term memory in Illustration 3b) (Roupé & Gustafsson, 2013).

Types of condition of the perceiver

26 As introduced above, beside senses, experience is affected by temporal conditions, in other words short and long term past experiences and future expectations. In fact, by

looking from the perceiver's point of view (Illustrations 1d, 1f and 3b), we can distinguish between *temporary* and *permanent* conditions affecting perception. Under the first category we can list the physical and mental conditions and emotions emerging during the act of experiencing (experience as feeling); for example, the perception of a place is affected by the road travelled to reach the location and the emotional/physical state of the individual at that specific moment; both are obviously directly influenced by the environment itself in that specific contextual situation. This set of variables can be considered as a *personal temporary condition.* Another specific temporary situation that influences perception is the *social transitory condition* if the person is alone, in a group or in a crowd; for instance, behaviour of people and even sensations change in relation to these different social situations, and people in groups generally feel less vulnerable (Hall, 1992 first edition 1966). Under the second category of permanent conditions, accumulated over time, we can consider the personal history, culture, education, professional skills and memories (experience as knowledge). In fact, long term experience is related to all the features that contributed to generate the person as he or she is. Even if evolving over time, we can call this a *personal permanent condition.*

27   Through memory, things are transformed and elaborated, filtered and selected, and sometimes augmented by personal significance over time. Hence, not only the present experience is influenced by the knowledge achieved, but sensory perception can contribute to recall even distant emotions and feelings. So, even the immediate past is strictly linked to the more distant one in a fluent and dynamic manner. In this constant stream, we also look forward and somehow envision the future. For instance, while walking we continuously receive inputs and clues from the environment, and this allows us to take decisions about our ongoing actions (near future); we see corners where we decide to change direction and targets that we are going to reach.

Types of condition of the physical environment

28   The physical world is an evolving system (Illustrations 1b and 3a). The built environment is mainly composed by architecture (buildings and open spaces) and urban furniture. In its first meaning it presents physical *permanent conditions*, namely conditions that are stable over time, while in the second one it presents physical *semi-permanent conditions*, like urban furniture which change more frequently and are more susceptible by external modification. On the contrary, nature and climate are only to some extent controlled by design: for instance, planting trees or installing shelters can contribute to controlling micro-climate conditions. In general, climate presents physical *recursive conditions*, e.g. seasonal and hourly cycles. Finally, *temporary conditions* are represented by the flows (people, cars, animal life). We can state that people are driven and informed by design, and not simply controlled; although spaces are designed according to the specific actions by people, such as driving, walking or loitering, people can freely move in space and have a fickle presence, even if it is possible to recognize recurrent trends over time. A similar categorization was proposed by Amos Rapoport when he defined fixed, semi-fixed and non-fixed feature elements (1982).

29   Finally, we attempt to introduce the role of simulation (Illustration 1e) within this sensory and cognitive process. We are able to interiorly imagine future (or past) environments that we never experienced starting from drawings or even textual descriptions alone, but we wonder how to test and share these mental constructions of

places in an effective and material way. Simulation should help in this sense, but it has to deal with two main issues and simplifications of perception: firstly, the simulation *per se* as a simplified but realistic and accurate restitution of the environment; and secondly, the process of re-sensing the simulated environment by the perceiver, thus introducing the topic of man-simulation interaction with all the consequent technical difficulties to faithfully reproduce this relationship (see for instance: Loomis et al 1999; Danahy, 2001).

Perceptual simulation: application to urban design and validity

30   The above attempt to reconstruct the man/environment relationship and the mechanisms of perception (Illustrations 1b, 1c, 1d and 1f), is the basis for exploring the parallel man/simulation connection (Illustrations 1e, 1c, 1d and 1f). In fact, our aim is to provide a framework for the modalities that simulation can activate in order to accurately recreate the corresponding man/environment relationships. Instead of considering simulation as a medium *per se* alone, it is important to establish its boundaries, relevant terms and its meaning, and therefore to redefine the main characteristics of perceptual simulation. In particular, according to the initial questions raised in the introduction to this work, in this section we want to address the main issues related to simulation for urban design. In particular, we start with visual simulations that can refer to a longer tradition of studies and theories, and we conclude with the opening to multi-sensory approaches, fostered by the advancement of immersive technologies increasingly applied both in the commercial and research domain.

31   In the following section we are going to first investigate the relevance of perceptual simulation for evaluating design schemes of urban transformation and, afterwards, we will investigate the reliability (validity) of simulation as a medium *per se*, the reliability of user interaction with simulation and the influence of external factors on simulation. In a similar way, Waller, Hunt and Knapp (1998) distinguish between *environment fidelity* (which refers to the medium) and *interface fidelity* (which refers to interaction with the medium).

The relevance of perceptual simulation in the professional practice

32   Architects along the creative process, and decision makers in the evaluation phase, face the difficult task of appraising design projects that will inevitably affect the life of people. In other words, we take decisions on future transformations, and often these are not correctly informed by media that would enable accurate anticipation of future conditions. Even with great experience, it is not easy to mentally fill the gap between static and generally mono-sensory (visual) descriptions of design projects, and correctly imagine their cumulative, evolving and multi-sensory outcomes in the real world. Moreover, since the perception of the environment changes according to the location of the observer in space (Bosselmann, 1998), tools that enable to study and anticipate future conditions from different locations can make the difference in governing the complexity of design. This does not mean that we have to produce a perfect copy of reality in one to one scale, but a certain degree of realism in its anticipation is essential (Bosselmann, 1998; Nasar, 1998). We argue that, accurate, perceptual simulation is a useful tool for depicting and

experiencing non-existing environments, even if it is a non-perfect and a reductive surrogate for real conditions.

Validity of the simulation medium per se

33 There are several studies dealing with the validity of visual simulation. Donald Appleyard was the first scholar to contribute a specific theory on this topic. He identifies two methods for verifying the quality of realistic simulations: "an assessment of responses and an analysis of the media images" (Appleyard, 1977, p.65). The first is related to the domain of environmental psychology, namely *ecological validity* (Brunswik, 1956) that is "the applicability of the results of laboratory analogues to non-laboratory, real life settings" (McKechnie, 1977, p.169), which implies a *response equivalence* between reality and its simulation (Appleyard, 1977, p.65). The second one focuses instead on the medium itself, and takes into consideration both the process of filming (shooting and processing) and the type of simulation.

34 Donald Appleyard, already in the 1970s, asserts that "the present world of experiential simulation is an idealized one where the sun always shines, vegetation grows in luxuriant profusion, the water is pure, the streets clean, the people well-dressed and happy; all is new, nature remains undamaged, and only pleasant vistas offer themselves to view. (...) The credibility of these simulations is now in question. The products do not always live up to the simulations" (Appleyard, 1977, p. 44-45). This is a crucial aspect not only in technical terms, but also from an ethical point of view, and has to do with the transparency of decision making processes.

35 Donald Appleyard (1977, p.57) affirms that simulation should be *realistic and accurate, comprehensible and evaluable, engaging, cheap and flexible.* Resuming this approach, Stephen R.J. Sheppard (1989, p.59) stresses that simulations have to be *understandable, believable* and *un-biased.* For the author these standards can be achieved through *representativeness, accuracy, visual clarity, interest, legitimacy*; when these criteria are not met, they can respectively generate *poorly understood or confusing simulations, unconvincing or mistrusted simulations* and *misleading simulations* (Sheppard, 1989, p. 64). Peter Bosselmann (1998, p. 199) recalls these principles indicating how simulations should be: *understandable, open to evaluation, complete, accurate, engaging, detailed* and *realistic* (in terms of response equivalence). For instance, the level of accuracy of virtual environments can affect evaluation by the simulation users and can depend on the level of detail of the simulation or on the technology used (Sheppard and Cizek, 2009).

36 In short, according to the above mentioned authors, biases related to the medium *per se* are the following: the correct localization of the environmental futures in space; the quality of the simulation in terms of description and representation of the features (level of detail and resolution; materials and textures, lighting and colours, shapes, and so on); the homogeneity of representation of environmental features (e.g. current condition vs. design schemes); the readability of the simulation in relation to human optics, including the considerations on resolution, foveal and peripheral vision (Dahany, 2001); the inclusion of features that recall the atmosphere of places (climate condition, clues to economic and social aspects like the level of maintenance of places) can unconsciously affect the understanding and evaluation of places; the inclusion of dynamic aspects within the depicted environment (Pietsch 2000, p. 252).

37   Finally, depicting multisensory features is the next step for improving the effectiveness of simulation. Even if it is more common to use visualizations to describe design projects, for the correct understanding of their cumulative impacts in terms of experience, other sensory aspects should be included. Unfortunately, in terms of anticipation of perceptual non-existing conditions, it is not easy (and sometimes expensive) to produce reliable sensory simulations. Even if some researches are working in this direction, the possibilities and versatilities of these sensory simulation products are still not comparable to the visual ones. Anyway, a number of clues within the visual domain hints to other sensory aspects of the environment. For instance, even if it is only indirectly perceived, the texture of the ground tells us something about the tactile sphere, clothes of people and vegetation let us assume the period of the year and the thermal comfort experienced in the place, and heavy traffic predicts noise and pollution. Moreover, as Yi-Fu Tuan says, "a child of three years old is already able to project himself kinesthetically into the illustration of his book".

Validity of the user/simulation interaction

38   In order to reproduce an analogue perceptual man/environment relationship through simulation, the medium itself should be correctly produced, but also the user interaction to it. Three relevant issues can affect the efficacy of simulation from an experiential point of view, as follows.

39   The first aspect is the *perceptual relationship* occurring between user and simulation (distance and location). For instance, in terms of visual perception, this is mainly due to the ratio between the size of the simulation and the position of the perceiver (Bosselmann, 1998); ideally, the observer should be placed at the same point of view of the recording point of the simulation in terms of distance and location, adequately scaled.

40   Secondly, we have to take into account the *dynamic aspects* in interacting to simulation. The motion of temporary elements (Illustration 3a) within the simulation and the movement (eye, head, body) of the user in relation to the depicted space are crucial to realistically reproduce the sense of experiencing a place (Klatzky et al, 1998; Danahy, 2001; Roupé et al, 2013; Lange, 2005). In fact, different techniques of interaction to simulation (for instance desktop versus head-mounted display) influence the acquisition of spatial knowledge (Pausch et al, 1997; Lathrop & Kaiser, 2002); in any case, a proper setting increases the sense of realism (Riecke et al, 2010), but in doing this it can also be misleading: the user should always be aware of the limits of the tool and in particular what the simulation cannot reproduce and is consequently not telling the hidden features.

41   Thirdly, the *reactivity* of the simulation in terms of responsiveness to the stimuli inducted by the user to the simulation. The user is a passive perceiver of the simulation, but also an emitter who actively provides new inputs to the virtual environment (Illustration 1c). For instance, the user emits noise while walking through the simulation, leaves traces on the ground, occupies space and thus induces other elements to react, and so on. This domain can take advantages of techniques transferred from procedural or agent-based simulations (Lange, 2005).

### Validity of the simulation affected by external factors

42   Even if some forms of distortion are due to the simulation itself (the medium and construction of the simulation) and man-simulation interaction, others are a consequence of external factors, like the presentation format of the simulation, which refers to the context where the simulation is displayed, and the user's personal background. In fact, the atmosphere of the place where the user is introduced to the simulation together with (or without) the act of presenting and communicating simulations, highly affect people's approach to it: the "perception of the simulation is affected by the social and physical surroundings as much as by the simulations themselves" (Appleyard, 1977, p.54). Another external factor affecting the evaluation of simulation relates to the personal or social background of the observer, which might be influenced by prejudices for or against the proposed design scheme. Peter Bosselmann and Kenneth H. Craik identify four sets of variables that, independently from the type of simulations, influence user evaluation: "1. characteristics of the observers (e.g. environmental attitudes and dispositions; professional training); 2. medium selected for presenting the settings (i.e. how the place is encountered, e.g., via direct site visit, photo-slides, scale models, sketches); 3. the response formats used and the range of reactions they encompass, and 4. the environmental attributes of the settings" (1985, p. 4).

Reframing perceptual simulation media

43   Following the previous considerations, we can finally link the theoretical framework about the process that links man, environment, design and simulation of reality to the tools. Each typology of simulation has its own usefulness, and knowing the capabilities of each medium is relevant to both tasks of design and evaluation. Hence, specifications such as static or dynamic, 2-D or 3-D, immersive or not immersive, contribute to the definition of the medium's possibilities in terms of user experience of a non-real environment (Piga, 2010). In fact, the gap between reality and simulation structures a conceptual architecture of the simulation tools. The first and main aspect to take into account is the degree of dynamicity of simulation.

44   George E. McKechnie (1977) firstly distinguished between perceptual/conceptual and static/dynamic simulation, where the first group discerns experiential/abstract simulation, and the second one their own characteristics, which in one case helps to highlight the environment as a system (dynamic), whereas in the other helps to freeze and study a single moment (static). In order to correctly define the typologies of media, we argue that we have to consider simulation/observer interaction instead of the intrinsic characteristics of the tools only. According to this approach, the static/dynamic distinction provided by McKechnie (1977) should be re-modulated. Dynamic simulations are the ones that enable a motional perception of the depicted environment. Even a *static* image can be considered *dynamic*, if it is big enough to ensure the user can visually wander inside the boundaries of the canvas: panoramic images are a typical example of this category (Danahy, 2001). Static simulations, on the contrary, do not allow this kind of motional interactivity. Following the same approach, each type of simulation can be redefined according to the possibilities it guarantees in terms of fruition of the scene.

45 The final goal of this categorization is twofold: firstly, it aims to reconstruct the architecture of the tools used by research and in professional practice according to a series of conceptual categories as represented in Illustrations 4 and 5 in the form of a comprehensive matrix; secondly, by giving meaning and insight to different types of simulations, we can touch the ultimate sense of their role within the design process. In short, the novelty of the proposed 'matrix of tools' does not rely on the innovation of the single applications themselves, but on the comprehensive reconstruction of the overall picture, which orients the work on simulation in urban design. For instance, simulation assumes a different value and significance depending on the way and at which stage of the process it is applied (i.e. conception, project development, internal validation by designer, external evaluation and public communication).

Illustration 4: The matrix of simulation tools
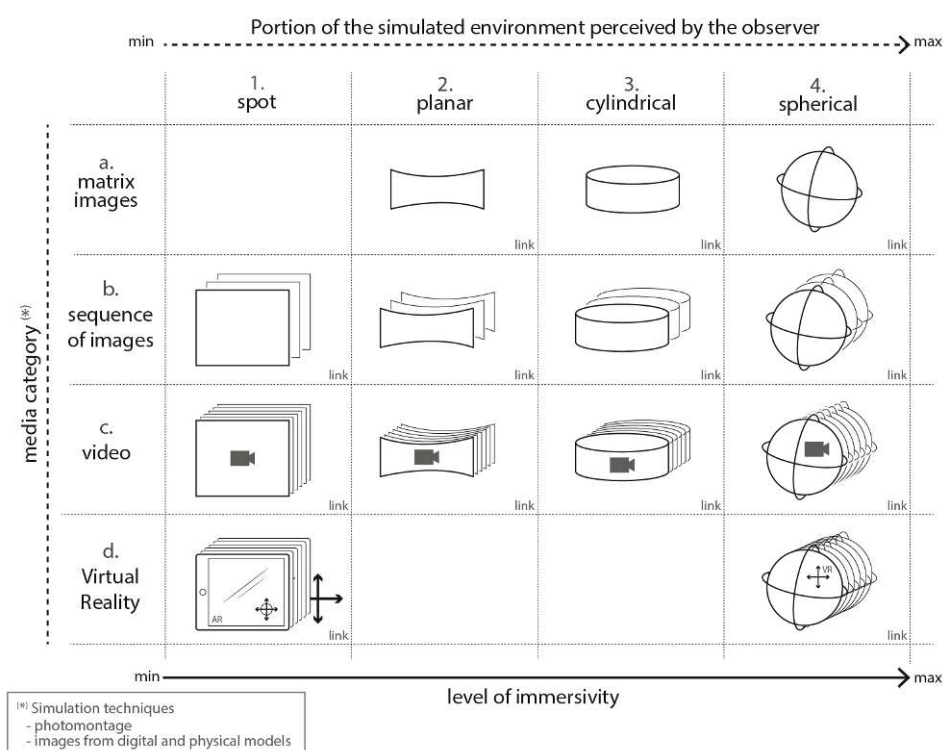
Man/Simulation relationship and the 2-D media that enable dynamic perception. See the online version where the cells of the matrix recall multimedia objects: http://www.labsimurb.polimi.it/skillsandtools/visualscape/2D.html (consulted on July 20, 2015)
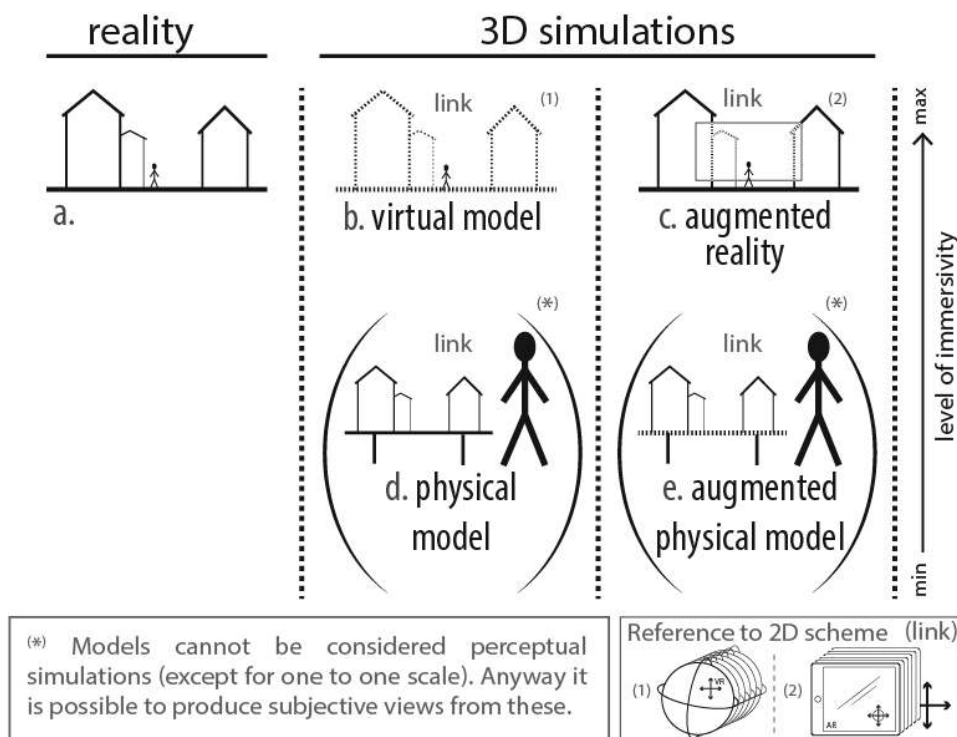
SOURCE AND COPYRIGHT: THE AUTHORS

46 In Illustration 4 we organized the categories in columns according to four main typologies of media: *matrix images*, *sequences of images*, *videos* and *Virtual Reality*. Depending on the way they are prepared, these media allow a dynamic perception with an increasing sense of immersivity (represented in the rows), passing from *spot* perception (not panoramic), where the dimension of the angle of view of the simulation is smaller than the real field of view, to different types of panoramic perceptions, where the view-angle of the simulation is equal or bigger than the observer's one. Hence, according to the level of immersivity (from *planar* to *cylindrical* and *spherical* perception of the depicted environment), these typologies of simulation permit to look around; interactive fruition dramatically increases the sense of realism (sense of place) and thus engagement and

understanding (Appleyard, 1977; Bosselmann 1998, Loomis & Blascovich 1999; Danahy 2001; Lanthrop 2002; Bishop & Lange, 2005; Lange, 2005; Plank et al, 2010; Roupé & Gustafsson 2013). For instance, looking around using an endless panorama (spherical) is more realistic than being confined within the borders of a planar one, thus influencing the sense of engagement. Nevertheless, the choice among the different media is always a balance between the final goal and the resources at hand.

47   The peculiarities of simulation types influence communication of the content, because the emphasis is placed on one aspect rather than another. For instance, simulated projects superimposed on real videos take advantage of the realism of the context (façades, people moving and so on), but depict a current condition of the physical context that may change through the proposed transformation (e.g. flows of people and traffic could be affected by the project); on the contrary, at the current state of development, Virtual Reality allows to move freely in the simulated environment, but the level of detail is less realistic besides being time consuming in production. This implies that it is not possible to produce a perfect simulation but, at the same time, this emphasizes the need for a deeper understanding of the actual cognitive abilities in relation to the simulation media exploited or to be exploited. In short, the proposed matrix should serve as a tool itself in order to orient the choice among different available techniques of simulation, according to the principles of economy and accuracy. In fact, depending on the finalities of a simulation, the most suitable technique that allows to achieve the prefigured target with the highest degree of efficiency can be selected. Often mixed techniques, such as photomontage, can speed up the process achieving a better cost-benefit balance (Danahy, 2001).

Illustration 5: Man/Simulation relationship

3-D MEDIA THAT ENABLE DYNAMIC PERCEPTION.

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48   Illustration 5 represents 3-D models that enable a dynamic and a real volumetric perception of the environment. Digital models only give the illusion of tri-dimensionality, being confined within a planar screen; on the other hand, physical scale models are real and can directly be measured and handled. While in the first case it is quite easy to add dynamic elements, in the second one it is more difficult, even if feasible with some effort. On the contrary, the immateriality of digital models and their intangibility make them more distant and ephemeral to the observer, as opposed to the physical ones. In any case, these and other characteristics show how the two types of models must not be seen as alternatives, but rather as complementary (Piga, 2010). For this reason mixed solutions emerged, in particular with Augmented Reality. In some cases virtual models can be taken on-site and virtually superimposed on the real environment through a screen (Illustration 5c). In other cases, physical models are augmented with digital elements in order to include additional features, such as daily shadowing or traffic flows in motion; this is the case, for instance, of the *luminous planning table* (see for instance the *Tavolo Luminoso* project[1] in Cibien et al, 2011). The two applications of Augmented Reality allow different usage and open up to different uses, e.g. in one case bodily being and feeling the context or, in the other case, having the urban area at hand for in vitro studies. We should point out that with physical models the only way to achieve perceptual simulation is to produce a one-to-one scale model (not so easy and common) or to project a video or image from inside the model, in order to get subjective points of view, which, of course, recall the previous scheme (Illustration 4). Using a gantry with an endoscopic camera running through the model was the work modality of the first urban simulation laboratories, like the Environmental Simulation Laboratory at the University of California at Berkeley (McKechnie, 1977, p.174). Surprisingly, examples of one-to-one scale models located in the real environment, as prototypes for the project approval, exist; for instance, a Swiss law requires to install a fake building wireframe on site before getting the final approval of the project.

49   Finally, addressing temporary aspects of simulation (refer to Illustration 3) like flows of people, plant life and seasonal changes of vegetation, daytime and night-time conditions, requires dynamic and, even, interactive tools. Game engine technologies are a valid solution to give back the complexity of environmental settings: for instance, the user can select different conditions of time and dynamics occurring within the simulated environment, thus getting a fast understanding of the alternative atmospheres (Illustration 4: d/4). Moreover, integration of agent-based simulation into the model (i.e. flows like people, cars) could definitely enrich the perception of livability of the depicted environment. While simulation is representing non-existing environments, anticipating how *temporary conditions* will happen inside fictional environments is a crucial condition, and this requires applying procedural simulation techniques.

Conclusions

50   This article explores the process of man/environment interaction in order to understand the degree of fidelity of experiential simulation in reproducing places for urban design purposes. The authors argue that the tentative reconstruction of the sensory and cognitive processes of perception is an essential step for establishing a theoretical framework for urban simulation. Work on urban simulation and the restitution of virtual environments requires us to clarify a series of questions about the mission of simulation,

its potentialities and limits within the man/environment relationship. Hence, we have investigated the relationship between physical/simulated environments and the perceiver, the available techniques to approach perceptual and experiential simulation in urban design and the characteristics and purposes of available tools.

51   Even if the distance to reality is assumed as an unavoidable condition of simulation, nevertheless the attempt to improve the techniques – and consequently the reliability – of simulation constitutes the continuous effort of our research, aiming to get direct feedback on urban design practice. Hence, enabling people to feel the ambiances of places represents the ultimate goal of experiential simulation that incrementally, and thanks to the advancement of technology, gets closer – but will never correspond – to the physical features that concur in composing the physical space and atmosphere of places.

52   We argue that in the near future the advancement of ICT will enable simulation to become cheaper and less time consuming and manageable within the design practice, thus radically changing the approach both to design thinking (education) and the process of decision making (public evaluation); in fact, simulation will contribute to improve information on the outcomes of design and consequently involve laymen and decision makers in a more effective way. Future work will strengthen the technical expertise on simulation, especially by augmenting the role of sensory aspects and try to diffuse the advancements of the techniques into the design practice and education.

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NOTES

1. Some videos of the *Tavolo Luminoso* project are available at the YouTube channel of the Laboratorio di Simulazione Urbana 'Fausto Curti': http://www.youtube.com/playlist?list=PLcuVzk8EPrU_dRblJoWiCodIbDh0JF5Wq

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ABSTRACTS

Perceptual simulation represents an attempt to anticipate physical reality, whereby people can experience and interpret future environments from a subjective perspective. Working on experiential simulation for urban and landscape design requires an understanding of the relationship between man and the environment from a perceptual and cognitive standpoint. In fact, only by investigating the sensing and cognitive processes behind perception can we establish an informed approach to simulation of places and their ambiances. In particular, we propose a parallelism between man/environment and man/simulation relationships, aiming at giving back a framework for replicating in simulation the multisensory aspects that occur in the perception of the physical world. Hence, the objective of this article is to present how we approach the dimension of perceptual simulation within our research and professional work as urban designers. From a methodological point of view, we explored the topic through two main tasks, namely the selection and reconstruction of the research context and the key issues of perceptual simulation finalized in the second task, i.e. the construction of a set of simulation tools for urban design, intended as a matrix of possible practical applications. In particular, the theoretical framework presented in this work consists of a selection and overview of references relevant to urban design, comprehension of the research context and delivery of the set of tools implemented within our research unit. This matrix of tools represents the novelty of this work and is intended as a practical reference for orienting the choice among different simulation tools within the urban design practice. For instance, it is important to highlight the efficacy of each type of simulation in mimicking the man/environment relationship.

La simulation perceptuelle représente une tentative pour anticiper la réalité physique, offrant aux gens les moyens d'expérimenter et d'interpréter des environnements futurs dans une approche subjective. Travailler sur la simulation expérientielle pour le design urbain et paysager demande une compréhension de la relation entre l'Homme et l'environnement, d'un point de vue perceptuel et cognitif. De fait, c'est seulement en investiguant les processus sensoriels et cognitifs derrière la perception que nous pourrons établir une approche éclairée de la simulation des lieux et de leurs ambiances. Nous proposons en particulier de faire un parallèle entre les relations Homme/environnement et Homme/simulation, avec pour objectif de donner un cadre pour reproduire par la simulation les aspects multisensoriels de la perception du monde physique. Ainsi, l'objectif de cet article est de montrer comment nous approchons la question de la simulation perceptuelle à travers nos recherches et notre pratique professionnelle en tant que designers urbains. D'un point de vue méthodologique, nous avons exploré cette question à travers deux grandes taches, à savoir la sélection et la reconstruction du contexte de recherche, et les questions clés de la simulation perceptuelle, c'est-à-dire la construction d'un ensemble

d'outils de simulation pour le design urbain, vu comme une matrice pour des applications pratiques. Plus précisément, le cadrage théorique présenté dans ce travail consiste en une sélection et un aperçu de références pertinentes pour le design urbain, la compréhension du contexte de recherche et la présentation de l'ensemble d'outils développé dans notre unité de recherche. Cette matrice d'outils représente la nouveauté de ce travail et est conçue comme un guide pratique pour orienter le choix parmi les différents outils de simulation du design urbain. Par exemple, il est important de souligner l'efficacité de chaque type de simulation pour la reproduction de la relation Homme/environnement.

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