Aesthetical cognitive perceptions of urban street form.
Pedestrian preferences toward straight or curvy route shapes.

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D'Acci L. (2019). Aesthetical cognitive perceptions of urban street form. Pedestrian preferences toward straight or curvy route shapes. ***Journal of Urban Design***

Abstract
Human perceptions of space is not purely metric. Route angularity and complexity-minimizing paths suggest that pedestrians, consciously or not, tend to reduce the number and the angle of turns when selecting routes. Decisions involving route selection are different when the main criterion is not the orientation but the aesthetics of urban forms. This paper indicates that 80% of a stratified random sample of 102 people stated to prefer, *ceteris paribus* and for continuous/legible routes, to walk throughout curvy paths instead of straight and felt the former as shorter too; to generically walk through a route, and to reach a destination.

Keywords Street preference, pedestrian behaviour, environmental psychology, urban morphology

1. Introduction
Comprehension and prediction of pedestrian walking trajectories and preferences is attracting the attention of scholars from multiple sectors. Despite the relatively large multidisciplinary literature growing up on the topic, the inter-relationship between walking trajectories chosen and the pedestrian's perception of the environmental design attributes is often neglected (Nasir *et al*. 2014).
Lee *et al* (2014) noted in previous studies the lack of focus related to whether, and how, street structure affects pedestrians' path choice.

Understanding pedestrian preferences on street forms to walk through is beneficial for urban design generating pleasant and psychologically comfortable urban environments.
From an environmental point of view, promoting sustainable travel behaviour is a key objective to achieve a substantial reduction in CO2 emissions from transportation (EC 2011).
Walking is a key strategic transportation mode within cities which provides health benefits, social capital, relieves traffic congestion, preserves resources and vitalizes communities (Leyden 2003, Blanco *et al*. 2009).
To motivate citizens to walk it is necessary to take into account the urban environmental factors influencing their satisfaction of walking which form a polyhedric matrix of variables touching a variety of disciplines such as urban planning, architecture, environmental psychology, transport planning, sociology and geography.
Factors influencing walking behaviour are separated into two macro categories: interaction with the environment, and interaction with other users. Four sub-categories define the interaction with the environment: pedestrian network; pedestrian environment; infrastructure provision-management; land use and urban form. And two sub-categories define the interaction with other users: interaction with other pedestrians; interaction with traffic (Hodgson, Page and Tight 2004).
Wang, Chau, Ngb and Leung (2016) offer a vast recent literature review of physical built environmental attributes enhancing walking; focusing on the first of the above two macro categories, scholars have described built environmental characteristics influencing individuals' walking behaviour including land use form (Frank, Schmid, Sallis, Chapman, & Saelens, 2005), street connectivity (Owen et al., 2007; Shigematsu et al., 2009), aesthetic appearance of the surrounding environment and pleasantness of sceneries (Owen et al., 2004; Giles-Corti & Donovan, 2002; Inoue et al., 2010; McCormack et al., 2004; Van Dyck et al., 2013); City sprawl (Lopez & Hynes, 2006) and unpleasant vistas (Ball et al., 2001; King et al., 2000).
Also Ferrer *et al* (2014, Appendix A. p 156) provide an extensive organized list of built environmental factors associated with walking and their positive or negative effects on walking.
Camillo Sitte's *City Planning according to Artistic Principles* (1889) was followed by other masterpieces of literature unfolding qualities that urban areas should have to be pleasant and prosperous (Appleyard, Gerson, Lintell 1982; Hillier 2007; Alexander 1965; Alexander et al 1987; Anderson 1986; Bacon 1967; Jacobs 1961; Lynch 1981; Southworth 2003; Jacobs, Appleyard 1987), and, more specifically, relations between urban design and perceptions of a moving person were underlined since Cullen's work in the second half of last century (Cullen 1971).
Since then an extensive modelling apparatus explained and simulated moving person trajectories (Papadimitriou, Yannis and Golias 2009), in which route choice, navigation, path finding and crossing intersections are the most common behaviours investigated (Xi and Son 2012).
There are mainly three microscopic modelling approaches: the social force model (Helbing 1991), the cellular automata (Batty 2015), and the agent-based model (Terna 2015, Wilensky and Rand 2015).
The social force model is a continuous deterministic approach based on socio-psychological forces treating the surrounding environment as an attractive and repulsive magnet for pedestrians' trajectory.
The cellular automata is a discrete deterministic-stochastic approach translating the urban surface into a grid of equal cells having certain attributes which, according to a transition matrix

providing pedestrians' rule-preferences, determines how pedestrians move from one cell to the adjacent based of these attributes.

The relatively more recent agent-based models, contrarily to the cellular automata and the social force models, are heterogeneous in nature; they are able to model a multitude of different agents (pedestrians) characteristics-preferences by a multi set of if-then rules capturing a large variety (technically infinite) of pedestrian profiles.

In all the above model approaches, and at whatever macro, meso, micro level, it is critical to know how to build equations, codes and rules computing pedestrian street choice and walking behaviours.

Within the many factors influencing pedestrian street choice, we analyse the street's shape effects on pedestrian preference.

Besides modelling applications, this paper is also relevant to urban design and planning: new cities are appearing, growing and/or transforming; in an urban world which is trying to (re)create the human sense of *urbanity*, it is pertinent to know which urban form makes people feel more comfortable.

The shape of streets is a constituent of urban form[1] and knowing which street shape pedestrians prefer, specifically between straight lines or sinuous, is very timely in an epoch of post mega grid urban forms initiated last century by Pugin (1836), Sitte (1945), Ruskin (1849) and Morris (1891). While the orthogonal street grid of the Harappian, Egyptian, and Greek gridiron town layout, the Roman Centuriation and the Chinese Zhou modular urban geometry of the ancient cities were covering grids of a few hundred meters a side, urban grids such as European American colonies or the Barcelona of Cerda', extend for tens of kilometres and worsen from the mega blocks pattern: this scale difference is determinant for the perception of a human environment.

From a wider angle, different approaches explore factors potentially influencing landscape preferences: "the evolution theory, for example, argues that based on a common evolutionary background, there is a common preference or aversion for landscape features based on innate, biological reasons; see, for example, the prospect-refuge theory (Appleton, 1975) or the information processing theory (Kaplan & Kaplan, 1989) [or from an even wider angle see also Wilson 1986, 2004]. Other theories highlight that landscape perception and preferences are shaped by learned behaviour and people's cultural background (Zube, Sell, & Taylor, 1982). It is most likely that both evolutionary and cultural background shape landscape preferences (Arnberger & Eder, 2011; Tveit, Ode, & Fry, 2006)" (Häfner, Zasada, van Zante, Ungaro, Koetse & Piorr 2018).

2. Perceptions of street shapes

Agrawal et al (2008) found that only 21% of a sample of 328 respondents rated as "Not important" the aesthetic elements of the build environment in influencing their route choice, while for the rest 79% is "Very important" or "Somewhat important".

The British-Canadian psychologist and philosopher Berlyne was one of the first (Berlyne 1974) in formalizing beauty with a general model of aesthetics based on four components of an environment: complexity, novelty, incongruity, and surprisingness. He also suggests an inverted-U relation linking "hedonic tone" (pleasantness), with "uncertainty-arousal" (stimulations, explorations): as uncertainty increases, also hedonic level increases, but after a

[1] For more insights about urban form see D'Acci 2018-2019.

certain point decreases. The “happiest” feeling, or most pleasant appreciation of a scene, is for an intermediate level of visual stimulations, not too low neither too high.
Qualitatively similar results somehow close to the Berlyne inverted-U, came from fractal studies (Hagerhalla, Purcella,Taylor 2004; Taylor, Spehar, Van Donkelaar, Hagerhall 2011), about landscape views, where the latter are quantified by the fractal dimension[2] (the higher the more intriguing, detailed, rough, visually complex, irregular the scene is), and the highest level of preference is for medium values of the fractal dimension range of the visual scenes: neither too simple nor too complicated.
Processes involved in the perception of space relate to environmental psychology and spatial cognition. Bell, Fisher and Loonis (1978) defined environmental psychology as “the study of the interrelationship between behavior and the built and natural environment”. It is a psychology of space analysing individual perceptions, attitudes and behaviors in relation to their environment. Its conceptual framework was established in the 19th century until consolidating its own area of research in the 1960s. “Rather than a specific branch or specialized sub-discipline of psychology, environmental psychology is an interdisciplinary social science which draws from geography, anthropology, sociology, public policy, education, architecture, landscape architecture, urban planning, education, and psychology, especially social and developmental psychology” (Gieseking 2014).
Spatial cognition[3] gives noteworthy inputs to the studies of urban layout geometries and synergistically links disciplines such as environment psychology, urban design and spatial analysis; it is the study of perceptions, thinking and reasoning about spatial properties.
Starting with Lynch (1960) in the architecture and urban environment, Lowenthal (1961) in the geography, Trowbridge (1913) and Tolman (1948) in cognitive psychology and science, spatial cognition indicates that there is a difference, sometimes substantial, between physical space and mental space.
Studies in spatial cognition (Egenhofer, Mark 1995; Montello, Freundschuh 2005; Kitchin, Blades 2002; Mark, Smith, Tversky 1999; Montello, Freundschuh 2005; Stevens, Coupe 1978; Tversky 2003) show how the physical space and the one we perceived differ: “spatial knowledge is not veridical with physical space but is distorted *systemically*” (Rashid 2016, p. 22). This human cognitive spatial distortion is not because of some mind-brain glitches but is how our minds systemically work (Portugali 2011).

[2] Some intuitive definitions: “[…] fractal dimension ‘quantifies the cascade of details’ in an object. That is, it quantifies how much detail you see in all scale as you dive deeper and deeper […]” Mitchell (2009).
And some intuitive meanings in aesthetic/forms applications: “fractals […] dimension lies between the dimension that they are defined by and the dimension of the space they are trying to fill” Batty (2013). “Fractal geometry […] can be used to compare irregular forms […] measuring the geometrical complexity […] morphometric measurements” Thomas, Frankhauser (2013). “Fractal analysis can provide a synthetic measurement of place complexity and thereby allow a numerical characterization of places […] potential of using fractal dimension as a way of ‘quantifying the qualitative’ in terms of urban character […]” Cooper (2005). “In cities […] fractal dimensions […] becomes the signature of urban morphology” Batty (2013).
[3] "Spatial cognition concerns the study of knowledge and beliefs about spatial properties of objects and events in the world. Cognition is about knowledge: its acquisition, storage and retrieval, manipulation, and use by humans, non-human animals, and intelligent machines. Broadly construed, cognitive systems include sensation and perception, thinking, imagery, memory, learning, language, reasoning, and problem solving. In humans, cognitive structures and processes are part of the mind, which emerges from a brain and nervous system inside of a body that exists in a social and physical world. Spatial properties include location, size, distance, direction, separation and connection, shape, pattern, and movement” (Montello 2001).

Parts of these distortions refer to evaluating geometries firstly starting with topology and only secondly adjusting with metrics instead of the other way round, or, of only metric assessments (Montello 1992; Kuipers 1978; Piaget, Inhelder 1956).
"Human thinking and perception of spaces are not simply metric" (Blanchard, Volchenkov 2009, p. 22); scholars agree that spaces are psychologically translated.
Dalton (2003), shows that people "appear to be attempting to conserve linearity throughout their journey […] choosing the straightest possible routes as opposed to the more meandering routes. This particularly significant result supports hypotheses made by Hillier (1997) in which he stated that people tend to follow the longest line of sight that approximates their heading" (Dalton 2003, p. 107). As a justification of it, Dalton recalls Tolman (1938), Sadalla and Montello (1989), Montello (1991), and indirectly also Miller (1956), concerning human memory and complexity: keeping the straightest route, deviating as little as possible, reduces complexity; people may unconsciously prefer a straight path as a complexity-minimizing strategy (Dalton 2003, p. 126).
However, an essential point here is how much one knows the area in which she is navigating (i.e. walking or cycling). If we are talking about citizens walking in their own city, or in neighbourhoods that they know well (as usually is the case for residents) we may wonder if we should pay attention to the above complexity-minimizing strategy or if we can just focus on what kind of paths they actually prefer and feel more comfortable to walk through. They probably wouldn't be worried to get lost, or to forget how many times they should turn to reach the destination, or to get disorientated because of turning many times: we assume that residents know their own streets and places very well and don't need to memorize how many changes of direction they did or should do; they know these streets by heart.
Another point deserving attention is if one (regardless of her knowledge of the area) walks along a street without intersections or ramifications into other streets. In this case one cannot get lost anyway because there is only one path to follow, no matter its geometry (straight or sinuous). This is also the case of a street which even if it intersects other streets (or ramificates into other streets), it holds a strong identity and a clear continuity (i.e. because of the relative size, or aesthetics, contents, name…); namely a street which is very easy to be recognized as being *the same street* even if not geometrically linear and/or even if crossing many streets at various angles.
Apart from this, Dalton didn't ask her thirty participants at her virtual street environment test "which route would you *prefer* to go from x to y", but "were instructed to walk […] by the *most direct* route possible" (Dalton 2003, p. 108): what was asked was the *most direct* route possible so we shouldn't be surprised about the results.
Scholars supporting the least angle change route, also refer to the *route angularity* cited in Tolman (1938), Sadalla and Montello (1989), Montello (1991), as the "phenomenon of judging a route that contains many changes of direction to be longer than a straighter route of identical length" (Dalton 2003, p. 126).
Garling and Garling (1988) pointed out that "path minimization [in terms of time or distance] may not be adopted by pedestrian in all setting", however "is a dominant characteristic of the observable routine movement within a city […] minor changes in direction tend to be preferred over great changes in direction, perhaps because of an innate human tendency to avoid getting lost" (Zacharias 2001, p. 10).
Nevertheless, when analysing these observations of real people's movements, we should reflect about who the subjects are (citizens knowing very well their own areas, or not, and investigating further if this happens also for the former), what their movement purpose is and

what the content and context of the streets are (high buildings, shops, empty spaces, noisy, dirty, elegant …).
Montello (1991) also found that people are more comfortable in orienting in straight route patterns. He asked sixty pedestrians who were stopped in a neighbourhood to indicate the locations of several targets not visible from their own position. "Results demonstrate that environmental orientation depends in part on the angularity of route structure, the disorienting effect of oblique routes being due to memory distortion or imprecision associated with oblique routes […] as hypothesized, subjects generally pointed with greater accuracy when standing on the orthogonal street […] than when standing on […] oblique street" (Montello 1991, p. 47, 63). The *preference* was not tested but the *orientation*.
This doesn't necessarily mean that to go from x to y people would prefer the straight path instead of oblique because they would orient themselves better; if they are not worried to get lost (because they know the area well, or because they want to randomly explore the area, or because there are enough indications [street names, panels…], …), they may simply follow the path that makes them more comfortable.
There are therefore two orders of analysis: one related to the *physical* street patterns analysis (*geometrically* oriented); one "adds" *attractions* to the latter (*geographically* oriented). *Space Syntax* (Hillier and Hanson 1984) is part of the first family, while *Place Syntax* (Ståhle, Marcus, Karlström 2008), of the second. Within the latter, *Isobenefit Lines* (D'Acci 2015) are an example in which *Psycho-economical distances* are proposed to compute "not just how fast, or cheap, or mentally easier it is to move among locations, but also how pleasant it is: you may choose one path instead of another not just because it is faster, cheaper or mentally easier, but because you like it more […] even if a route is longer, it may be more pleasant and therefore one might prefer it rather than a shorter but less pleasant one" (D'Acci 2015).
The comfort depends from several factors such as noise, aesthetics, sun/shadow, quietness/crowdedness, land use, and so on.
One of these factors is the *shape of the path* itself; the two research questions this paper wants to reply to/confirm, and to open a profitable discussion within the scientific community of Space Syntax are:

1. Keeping everything else constant, do pedestrians prefer a straight path over a sinuous?
2. Do they feel it shorter too?

Regarding the first research question, Kent (1989), Herzog & Miller (1998), Matsumoto *et al.* (1997), in line with Kaplan's dimension of mystery of his environmental preference theory (1987, 1988), pointed out that a spatial layout concealing exits and the space immediately out of view, such as curved streets, stimulates curiosity and therefore guides preferences. According to the Kaplan(s)[4], "we like scenes that are engaging and involving – scenes that contain some mystery […] Typical examples of scenes with high mystery are those featuring paths curving out of sight" (Bell, Greene, Fisher, Baum 2001, p. 43-46).
This was confirmed from Ewing and Handy (2009), who found that long sight lines are negatively correlated to the urban design qualities creating comfortable and pleasant feelings such as enclosure and human scale (Ewing, Handy 2009, tab 2, p. 72): "the layout of the street network can influence the sense of enclosure. A rectilinear grid with continuous streets creates long sight lines. These may undermine the sense of enclosure created by the buildings and

[4] There were two Kaplan: Steven and Rachel. They presented their research in this subject individually (Steven 1975, 1987; Rachel 1975) and together (1982, 1989).

trees that line the street. Irregular grids may create visual termination points that help to enclose a space […] The sign of the coefficients in the model are as expected, with long sight lines […] detracting from the perception of enclosure […] [and] detract from the perception of human scale" (Ewing, Handy 2009, p.74, 76, 78).
Zacharias states that the expectation of spatial new information just beyond the angle of vision is a "positive inducement to exploration" (Zacharias 2001 p.342), and more generally a certain level of spatial complexity is an important element to create stimulating human environments. Finally, another relevant consideration to take into account in these kinds of analysis is the separation between *exploratory* behaviour and *goal-directed* behaviour (Zacharias 2001, p. 13), and those between *understanding* and *exploration* of Kaplan S. (1987). Similarly to Berlyne's model, Kaplan's model organizes the preference matrix into four components: coherence, legibility, complexity, and mystery. The first two relate to understanding (comprehend the environment), the last two relate to involvement, exploration (stimulation, motivation).
Regarding the second research question, we partially[5] enter into the domain of scaling in spatial cognition. "Scaling refers to a large and diverse set of explicit-report techniques in which respondents directly express their beliefs about quantitative properties of the environment […] Quantitative means that properties are not just classified but rated or estimated at a metric level of measurement – interval or ratio" (Montello 2016). There are two main methodological traditions: psychophysics (from the 1800s) and psychometrics (from the beginning of the 1900s). Psychophysics respondents assess quantities of certain properties that can be later compared by the researcher with the real quantities *objectively* measurable (Gescheider 1997). Psychometric refers to properties *not objectively* measurable (e.g. preferences, personality traits, etc..) (Borsboom 2005).
Jansen-Osmann and Wiedenbauer (2004) used a psychophysical scaling method[6] to "explore the 'route-angularity effect' in spatial cognition, in which people think routes with more turns are longer than routes with fewer turns but of the same actual length (in fact, this and other research studies found the effect to be inconsistent, not found reliably)" (Montello 2016).
The next Figures 1 and 2 show a few examples of straight and curvy streets.

[5] "Partially" because, as we will see later in the questions of the questionnaire, we already informed the respondent that the two paths to compare are equally long; the respondent is not asked to quantify (somehow) the two paths, but to express a feeling about which path seems shorter.
[6] Specifically, they used the ratio estimation method, in which respondents draw or indicate lines/shapes to express their own estimated measure of some quantity relative to a standard line/shape representing a standard quantity. In contrast to ratio estimation, another method is the magnitude estimation where respondents provide directly a number to estimate their perceived quantities relative to some standard quantity given in number.

Fig. 1 Source: Author's photo from Dordrecht, Copenhagen, Boston, New York, Glasgow, Den Haag and Milford-on-Sea

Fig. 2 Source: Author's photo from the New Forest (UK), Netherlands, Piedmont (IT) countryside

3. Street shape preferences from pedestrians: the questionnaire

Four images (Fig. 3-6) with two street scenarios each (A, B) were given to a sample of 102 respondents: 47.1% female, 52.95% male; 60.8% between 21 and 40 years old, 33.3% between 41 and 70, 3.9% older than 70, 2% younger than 20; 71.6% from western Europe, 12.7% from south and west America, 8.8% from Asia, 3.9% from eastern Europe, 2% from Africa, 1% from north America and Australia.

After underlining to imagine that both streets (A, B) are perfectly safe in the same way, they were asked "In which street do you prefer to walk?". The option was A, B or Indifferent. An additional open question also asked "why?" for each case.

The survey was conducted face to face (82) and online[7] (20), by providing figures and questions on a printed paper, and with a pen, respondents, randomly stopped in train stations, airports, refectories, bars, and parks (within the UK and NL), picked a reply, and, for the optional question ("why?") wrote their reply in a couple of lines.

As the goal is to know if, everything else staying constant, pedestrians have preferences regarding the shape of the street, and if so, which preferences, the *ceteris paribus* condition was ensured by proposing the same scenario for each pair of figures (same size of the streets, same pavements, same buildings, same colours, same density, same urban furniture, same

[7] In the face to face version there was neither interaction nor verbal indications, in order to keep the situation identical with the online version. The same document was given, printed or online. The online version was given by email to people keeping in mind the stratification of the sample.

design, same functions, …) in which the only difference within each pair of figures is the sinuosity of the street.

Fig. 3

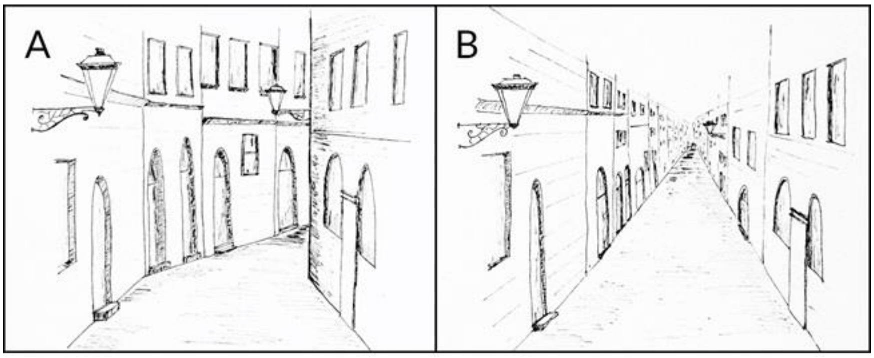

Fig. 4

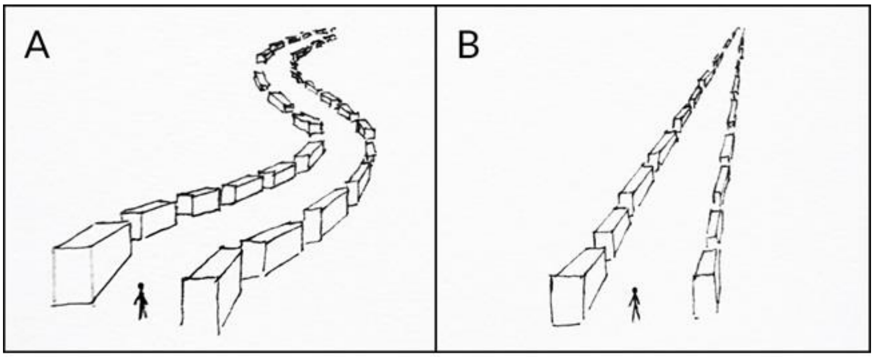

Fig. 5

Additionally, for fig. 5 it was also asked “Imagine to walk 1 km (around 15 minutes) along street A or street B. Which would you feel "shorter"? Do you perceive it to be "shorter" along A or B?”
The option was A, B or Indifferent.
Then for fig. 6 it was asked “To reach the garden which path would you choose?”. The options were A, B or Indifferent.

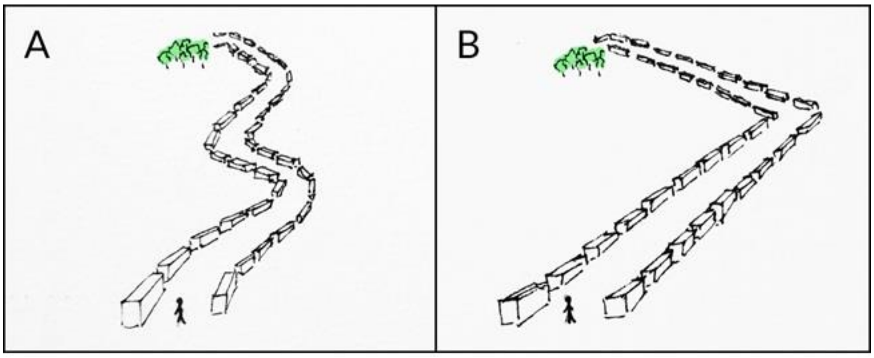

Fig. 6

4. Results

The large majority of respondents preferred the sinuous path against the straight in any scenario and any question (Fig. 7).
For the scenario in fig 1, 86.3% of respondents preferred to walk in the sinuous street, against 10.8% who preferred the straight street, while for 2.9% of respondents both streets were indifferent. The most frequent adjectives used to justify the preference toward the curvy street were cosy, intimate, romantic, prettier, more character, more interesting, less monotonous, seems shorter, more interactive.
Similar results appear for fig.4, even if in this scenario the number of people preferring the curvy street against the straight is a bit less (73.5% and 21.6% respectively), while 4.9% were indifferent.
According to the replies on the question “why?”, some people felt a slight claustrophobic feeling in the curvy scenario because of the small width of the street, while 73.5% preferring the curvy expressed the same adjectives for fig.3 plus picturesque, intriguing, variety.
The same reply is confirmed also for the scenarios of fig. 5 where 75.3% of respondents preferred the irregular street against the straight and expressing the following adjectives for the former: less boring, more dynamic, more exciting, more imaginative, feels shorter. 17.5% preferred the straight one, and 7.2% where indifferent to both scenarios.
For the same figure, 56.9% of respondents felt the curvy path as psychologically shorter than the straight one, even knowing that they are both the same length, 30.4% of respondents felt the straight as shorter, while for 12.7% of them both streets were equivalent in terms of psychological length.
The last scenario, fig. 6, and related question, added the *goal-directed* walk element, and also in this case the path with the highest angle changes was preferred: 84.4% preferred the route with more changes of angle (four changes); 11.7% the route with less changes of angle (one change); while for 3.9% both routes were equally fine.

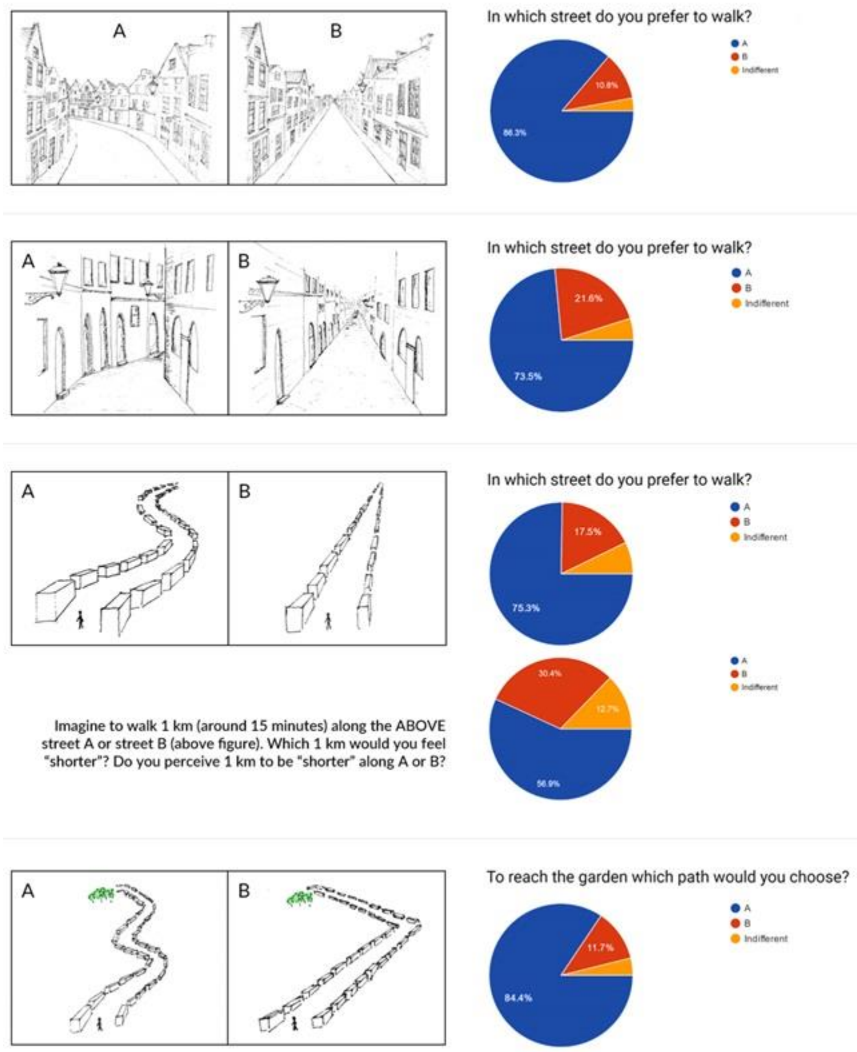

Fig. 7

Considering that, usually, *preferences* over a scene show greater individual variation than judgments of *quality* over a scene[8] (Bell, Green, Fisher, Baum, 2001, p. 40), this robust result is rather remarkable and deserves a deeper investigation with a larger sample and different approaches.

The limited size of the sub-samples per origin country of respondents doesn't allow to test for eventual geographical cultural influences, however, the three biggest sub-samples (Western Europe, Asia, and Central-South America with respectively 70, 12, and 13 individuals) show similar relative percentages in the replies.

The internal validity of this research result is consistent concerning the causality between expressed preference and street shape, as it is guaranteed by holding fixed all the other variables apart from the shape of the street, thanks to the drawings[9]. So that potential third

[8] For example, "several individuals may agree that a group of scenes is striking, untarnished, and of high scenic quality; nevertheless, one person may prefer desert landscapes, another mountains, and a thirf, seascpaes [...] (Im, 1984)" (Bell, Green, Fisher, Baum, 2001, p.40).

[9] For visual approaches (visual stimuli, real photos, photorealistic montages, digitally calibrated images, video-stated preferences) to evaluate landscape aesthetic preferences see, among many: Dachary-Bernard and Rambonilaza, 2012; Grammatikopoulou, Pouta, Salmiovirta and Soini, 2012; Dramstad, Tveit, Fjellstad and Fry,

variable problem is avoided and we can reasonably state the link between the preference and the shape of the street.
However potential internal issues may be the following: always having the curvy street on the left of the two pictures shown and the straight on the right; and being influenced from the aesthetics of facades (rather than preferring the street shape itself) that are much more visible on the curvy street drawing than on the straight one (for example if the facades were ugly, one could prefer to not see them and then choose the straight path for this reason alone). However, another question (fig. 5 and 6) asked the same but using neutral buildings (standard parallelepiped) to avoid this issue.
Regarding the external validity of these results, limitations of this questionnaire are: limited sample (even if such a high robust majority in the replies – around 80% expressing the same preference – easily allows for generalizations); deeper investigation of possible cultural/sex/age/education/country differences; potential divergences between stated preferences and revealed preferences[10].
The latter point should verify through observations in the real world the actual movement trajectories[11] and street decisions of pedestrians. If our goal is to isolate the single variable "street shape" (for a single continuous street, as in this study) or "path shape" (for a selected path along several possible street combination sequences during a walk), the task may be complicated, if not almost impossible, because of the practical impossibility to find streets/paths differing *only* in their shapes, or to be able to *well* quantify *all* the other differing variables (views, amenities, noise, facades, personal memories, …), or to isolate the reasons why pedestrians are walking in a street instead of another, such as for shopping, for work, schools, public transport, … : we may observe a large number of pedestrians in a street not so much because of the form of the street itself but for its content, and its content may not be directly or indirectly related to its shape, neither easily/properly quantifiable to insert in a multivariable analysis.
The open question ("Why?") of the questionnaire asking, in the respondent's words, to explain the reasons of her preference, helps the understanding of the individuals' systems of meaning, whose importance was emphasized throughout the last century[12] among anthropologists and

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2006; Arnberger and Eder (2001); van Berkel and Verburg, 2014; Orland, Daniel and Haider, 1994; Hagerhalla, Purcella and Taylor 2004; Taylor, Spehar, Van Donkelaar and Hagerhall 2011; Perdomo et al., 2014.

[10] The methodology of Stated Preference has its roots in traditional microeconomics consumer behaviour theories, in marketing and in preference theory (Häfner, Zasada, van Zante, Ungaro, Koetse & Piorr 2018; Louviere, Hensher, & Swait, 2000). Systematic bias in the Stated Preference method have been well known since a long time, however it can provide reliable indications about the true underlying preferences (Wardman 1988). In a study "in 80% of the respondents the stated and revealed preferences corresponded" (Lambooij, Harmsen, Veldwijk, de Melker, Mollema, van Weert and de Wit 2015). Stated preferences have been used for pedestrian preferences in many studies, such as Kelly et al., 2011, Kaparias et al., 2012. For a more general discussion about revealed and normative preferences see Beshears, Choi, Laibson and Madrian (2008).

[11] According to Hill (1984), pedestrian movement was the first use (Weiss and Boutourline 1962) of behavioural tracking. Behavioural tracking is, to use the Sommers (Sommer and Sommer 2002) terminology, within the family of individual-centered behavioural mapping (*movement* of individual/s in space). The other family of behavioural mapping is place-oriented (where individual/s choose to *locate* themselves in a particular space). Behavioral maps is "a technique for studying the relationships between behaviour and the physical space in which it occurs", this is the definition from Ittelson, Rivlin, and Proshansky (1970, p.349), who first introduced behavioural mapping to environmental psychology (Ng 2016, p. 31).

[12] As early as 1890, James, a leader of the (philosophical) movement of Pragmatism and of the (psychological) movement of functionalism, supported the importance of understanding how each of us interpret the world in our own unique way, in an idiographic approach, avoiding standard responses but studying each individual in their own terms. Concept emphasized in Allport (1937), a pioneer researcher on human personality (Carter 2016).

sociologists, particularly the structuralist (Douglas 1977, Canter 2016). From the replies we still saw a general strong similarity across individuals' meanings associated to street shape, as most of their adjectives are, more or less roughly, synonymous.
In figures 5 and 6 the views from above allow respondents to see the final destination (fig 6) and the entire path sequence (fig 5) which may create a different visual prospective from the real pedestrian view when actually walking, therefore biasing the result. However, we may also consider that this global vision from the drawing may compensate the situation in which pedestrians already know the street, therefore even without being able to see it all in one go (as from the drawing) she mentally "sees" it as she knows it well.

5. Conclusion

Factors influencing walking behaviours related to physical built environment attributes are listed, among many authors, in Hodgson, Page and Tight (2004); Wang, Chau, Ngb and Leung (2016); Frank, Shmid, Sallis, Chapman and Saelens (2005); Owen et al. (2007); Shigematsy et al (2009); Owen et al (2004); Giles-Corti and Donovan (2012); Inoue at al (2010); McCormack et al (2004); Van Dyck et al (2013); Lopez and Hynes (2006); Ball et al (2001); King et al (2000); Ferrer at al (2014); Cullen (1971).
Modelling approaches to route choice have been explored by, among many, Papadimitriou, Yannis and Golias (2009); Xi and Son (2012).
Specifically focused on perceptions of street shapes are Agrawal et al (2008); Beryline (1974); Hagerhalla, Purcella, Taylor (2004); Taylor, Spehar, Van Donkelaar, Hagerhall (2011).
Observations supporting that people tend to conserve linearity in their routes are in Dalton (2003), Hillier (1997), Tolman (1938), Sadalla and Montello (1998), Montello (1991), Miller (1956), Zacharias (2001): the questionnaire shows in this paper a different result when we don't invoke people's orientation perception but purely an aesthetical one.
Jansen-Osmann and Wiedenbauer (2004) suggest that people perceive longer the routes with more turns: this paper shows an opposite result also for this aspect.
In line with the findings of our questionnaire, authors emphasizing people's preferences toward more curved streets stimulating curiosity and mystery, are Kent (1989), Herzong and Miller (1998), Matsumoto et al (1997), Kaplan (1987, 1988), Bell, Greene, Fisher and Baum (2001), Ewing and Handy (2009).
Urban forms, such as street shape, influence our psychological perception of spaces and our behaviour which in turn determines our urban daily quality of life and our actions.
This paper adds to the literature the fact that pedestrians prefer curvy routes to walk along rather than straight, and feel the former shorter too. Especially the last point is of special interest as it is in contradiction with previous assumptions we described in the introduction. This has implications both for the urban design/planning arena and the spatial analysis models when they need to compute/weigh distances in their calculations of street network relationships and, especially, decisions involving route selection in the cases when the main criterion is not the orientation but the aesthetics (D'Acci 2019).

Bibliography

Alexander C. (1965). *A city is not a tree*. Archit Forum 122(1):58–62.
Alexander C. et al (1987). *A new theory of urban design*. Oxford University Press, Oxford.
Allport G.W. (1937). *Personality: a psychological interpretation*. Holt Saunders. New York.

Agrawal A.W., Schlossberg M., & Irvin K. (2008). How far, by which route and why? A spatial analysis of pedestrian preference. *Journal of Urban Design* Vol. 13, n. 81-98.

Anderson S. (ed) (1986). *On streets*. MIT Press, Cambridge, MA.

Appleyard D., Gerson S., Lintell M. (1982). *Livable streets*. University of California Press, Los Angeles

Appleton, J. (1975). *The experience of landscapes*. Wiley, New York.

Arnberger A., & Eder R. (2011). Exploring the heterogeneity of rural landscape preferences: An image-based latent class approach. *Landscape Research*, 36(1), 19–40.

Bacon E.N. (1967). *Design of cities*. Thames & Hudson, London.

Ball K., Bauman A., Leslie E., & Owen N. (2001). Perceived environmental aesthetics and convenience and company are associated with walking for exercise among Australian adults. *Preventive Medicine*, 33(5), 434–440.

Batty M. (2013). *The new science of cities*. MIT Press, Cambridge, MA.

Behbahani P.A., Gu N., and Ostwald M. J. (2014). *Comparing the properties of different space syntax techniques for analysing interiors.* In: Madeo F. and Schnabel M. A. (eds.) (2014). *Across: Architectural Research through to Practice: 48th International Conference of the Architectural Science Association* 2014, pp. 683–694. The Architectural Science Association & Genova University Press.

Bell P.A., Greene T.C., Fisher J.D., Baum A. (2001). *Environmental Psychology*. Taylor & Francis, New York.

Berlyne D.E. (1974). *Studies in the new experimental aesthetics: steps toward an objective psychology of aesthetic appreciation*. New York: Halsted Press.

van Berkel D. B., & Verburg P. H. (2014). Spatial quantification and valuation of cultural ecosystem services in an agricultural landscape. *Ecological Indicators*, 37(PART A), 163–174.

Beshears J., Choi J.J., Laibson D. and Madrian B.C. (2008). How are preferences revealed? *Journal of Public Economics*. Volume 92, Issues 8–9, August 2008, Pages 1787-1794.

Blanchard P., Volchenkov D. (2009). *Mathematical Analysis of Urban Spatial Networks*. Springer.

Blanco et al. (2009). Hot, congested, crowded and diverse: emerging research agendas in planning. *Progress in Planning*, 71(4) pp.153-205.

Boorsboom D. (2005). *Measuring the mind: conceptual issues in contemporary psychometrics*. Cambridge University Press. Cambridge, UK.

Canter D. (2016). Revealing the conceptual system of places. In Gifford R. (Ed.), *Research Methods for Environmental Psychology*. Wiley Blackwell.

Cohn, A. and D. Mark (Eds), Spatial Information Theory. *Lecture Notes in Computer Science* 3603, Springer Verlag: 473-490.

Cooper J. (2005). Assessing urban character: the use of fractal analysis of street edges. *Urban Morphology*, 9(2), 95-107.

Cosmides L., Tooby J. (1987). *From Evolution to Behavior: Evolutionary Psychology as the Missing Link*. In Dupre J. (ed.), *The Latest on the Best* (pp. 277–306), Cambridge, MIT press.

Cullen G. (1971). *The concise townscape*. Burlington. Architectural Press.

D'Acci L. (2019). Urban street morphology perception: orientational versus aasthetical parametrization in space syntax. *Spatial Cognition & Computation*. In press

D’Acci L. (2018). *On Urban Morphology and Mathematics*. In: D’Acci L. (Ed). (to appear 2018-2019) *Mathematics of Urban Morphology*. Birkhäuser (Springer), Cham.

D'Acci, L. (2015). Mathematize urbes by humanizing them. Cities as isobenefit landscapes: psycho-economical distances and personal isobenefit lines. *Landscape and Urban Planning*. Volume 139, Pages 63-81.

Dachary-Bernard J., & Rambonilaza T. (2012). Choice experiment, multiple programmes contingent valuation and landscape preferences: How can we support the land use decision making process? *Land Use Policy*, 29(4), 846–854.

Dalton R.C. (2003). The secret is to follow your nose. Rout Path Selection and Angularity. *Environment and Behavior*, Vol. 35, n. 1, 107-131.

Douglas M. (Ed.) (1977). *Rules and meanings*. Penguin.

Dramstad W. E., Tveit M. S., Fjellstad W. J., & Fry G. L. A. (2006). Relationships between visual landscape preferences and map-based indicators of landscape structure. *Landscape and Urban Planning*, 78(4), 465–474.

Egenhofer M.J., Mark D.M. (1995). *Naive geography*. National Center for Geographic Information and Analysis (US), Santa Barbara, CA.

European Commission – EC (2011). White paper. Roadmap to a single European transport area-towards a competitive and resource efficient transport system [COM(2011) 144]. Luxembourg: Publications Office of the European Union.

Ewing R., Handy S. (2009). Measuring the Unmeasurable: Urban Design Qualities Related to Walkability. *Journal of Urban Design*, 14:1, 65-84.

Frank L.D., Schmid T.L., Sallis J.F., Chapman J., & Saelens B.E. (2005). Linking objectively measured physical activity with objectively measured urban form: Findings from SMARTRAQ. *American Journal of Preventive Medicine*, 28(2 Suppl. 2), 117–125.

Garling T., Garling E. (1988). Distance minimization in downtown pedestrian shopping. *Environment and Planning A*, 20: 547-54.

Gescheider G.A. (1997). *Psychophysics: The fundamentals*. Mahwah. New York.

Gieseking J. (2014). *Environmental Psychology*. In Teo T., Barnes M., Gao Z., Kaiser M., Sheivari R., Zabinski B., (eds). *International Encyclopedia of Critical Psychology*. New York: Springer, 587-593.

Giles-Corti B., & Donovan R.J. (2002). Socioeconomic status differences in recreational physical activity levels and real and perceived access to a supportive physical environment. *Preventive Medicine*, 35(6), 601–611.

Grammatikopoulou I., Pouta E., Salmiovirta M., & Soini K. (2012). Heterogeneous preferences for agricultural landscape improvements in southern Finland. *Landscape and Urban Planning*, 107(2), 181–191.

Häfner K., Zasada I., van Zanten B.T., Ungaro F., Koetse M. & Piorr A. (2018) Assessing landscape preferences: a visual choice experiment in the agricultural region of Märkische Schweiz, Germany. *Landscape Research*, 43:6, 846-861.

Hagerhalla, Purcella ,Taylor (2004). Fractal dimension of landscape silhouette outlines as a predictor of landscape preference. *Journal of Environmental Psychology*, 24.

Herzog T. Miller E. (1998). The role of mystery in perceived daner and environmental preference. *Environmental and Behavior*, 30, 429-449.

Hill M.R. (1984). Stalking the urban pedestrian: a comparison of questionnaire and tracking methodologies for behavioural mapping in large-scale environments. *Environment and Behavior*, 16, 539-550.

Hillier B. (2007) *Space is the machine: a configurational theory of architecture*. Cambridge University Press, Cambridge

Hillier B. and Hanson J. (1984), *The Social Logic of Space*, Cambridge: Cambridge University Press.

Hodgson F.C., Page M. and Tight M.R. (2004). A review of factors which influence pedestrian use of the streets: Task 1 report for an EPSRC funded project on measuring pedestrian accessibility. Working Paper. Institute of Transport Studies, University of Leeds , Leeds, UK

Inoue S., Ohya Y., Odagiri Y., Takamiya T., Ishii K., Kitabayashi M., et al. (2010). Association between perceived neighborhood environment and walking among adults in 4 cities in Japan. *Journal of Epidemiology*, 20(4), 277–286.

Ittelson W.H., Rivlin L.G., and Proshansky H.M. (1970). *The use of behavioural maps in environmental psychology*. In Proshansky H.M., Ittelson W.H., Rivlin L.G., (Eds), *Environmental psychology: people and their physical setting*. Holt, Rinehart & Winston. New York.

Jacobs A., Appleyard D. (1987). Toward an urban design manifesto. *J Am Plan Assoc* 53(1):112–120.

Jacobs J. (1961). *The death and life of great American cities*. Vintage Books/Random House, New York.

James W. (1890). *Principle of psychology*. Holt Saunders. New York.

Jansen-Osmann P., Wiedenbauer G. (2004). The representation of landmarks and routes in children and adults: A study in a virtual environment. *Journal of Environmental Psychology*, 24 (2004) 347–357.

Kaparias I., Bell M.G.H., Miri A., Chan C., Mount B. (2012). Analysing the perceptions of pedestrians and drivers to shared space. *Transportation Research Part F: Traffic Psychology and Behaviour*, 15 (3) (2012), pp. 297-310.

Kaplan R. (1975). Some methods and strategies in the prediction of preference. In Zube E.H., Brush R.O., Fabos J.G. (Eds.), *Landscape assessment* (pp. 118-129). Stroudsburg, PA: Dowden, Hutchinson, & Ross.

Kaplan R., Kaplan S. (1982). *Cognition and the environment: functioning in an uncertain world*. New York: Praeger.

Kaplan R., Kaplan S. (1989). The visual environment: public participation in design and planning. *Journal of Social Issues*, 45, 59-86.

Kaplan S. (1975). An informal model of the prediction of preference. In Zube E.H., Brush R.O., Fabos J.G. (Eds.), *Landscape assessment* (pp. 118-129). Stroudsburg, PA: Dowden, Hutchinson, & Ross.

Kaplan S. (1987). Aesthetics, Affect, and Cognition: Environmental Preference from an Evolutionary Perspective. *Environment and Behavior*, 19(1), 3–32.

Kaplan S. (1988). *Where cognition and affect meet: a theoretical analysis of preference*. In J. L. Nasar (Ed.), *Environmental aesthetics: theory, research and applications* (pp. 56–63). Cambridge, UK: Cambridge University Press.

Kelly C.E., Tight M.R., Hodgson F.C., Page M.W. (2011). A comparison of three methods for assessing the walkability of the pedestrian environment. *Journal of Transport Geography*, 19 (6) (2011), pp. 1500-1508.

Kent R. (1989). The role of mystery in preferences for shopping malls. *Landscape Journal: Design, Planning and Management* 8, 1:28.

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge University Press, Cambridge.

King A.C., Castro C., Wilcox S., Eyler A.A., Sallis J.F., & Brownson R.C. (2000). Personal and environmental factors associated with physical inactivity among different racial–ethnic groups of U.S. middle-aged and older-aged women. *Health Psychology*, 19(4), 354–364.

Kitchin R., Blades M. (2002). *The cognition of geographic space*, vol 4. IB Tauris, New York.

Kuipers B. (1978). Modeling spatial knowledge. *Cognitive Science* 2(2):129–153.

Lambooij M.S., Harmsen I.A., Veldwijk J., de Melker H., Mollema L., van Weert Y.W.M. and de Wit G.A. (2015). Consistency between stated and revealed preferences: a discrete choice experiment and a behavioural experiment on vaccination behaviour compared. *BMC Medical Research Methodology*. 2015, 15:19.

Leyden K.M. (2003). Social capital and the built environment: the importance of walkable neighbourhoods. *American Journal of Public Health*, 93(9), pp. 1546-1551.

Lopez R.P., & Hynes H.P. (2006). Obesity, physical activity, and the urban environment: Public health research needs. *Environmental Health: A Global Access Science Source*, 5, 25.

Louviere J. J., Hensher D. A., & Swait J. D. (2000). *Stated choice methods: Analysis and applications*. Cambridge University Press, Cambrdige.

Lowntahal D. (1961). Geography, experience, and imagination: towards a geographical epistemology. *Annals of the Association of American Geographers* 51(3): 241-260.

Lynch K. (1960). *The image of the city*. MIT Press, Cambridge, MA.

Lynch K. (1981). *A theory of good city form*. MIT Press, Cambridge, MA.

Matsumoto N., Koyanagi E., Seta S. (1997). Physical and mental factors of anticipation in the streetscape. *Conference Proceedings of the Internation Conference on Environment-Behavior Studies for the 21st Century*, 4-6 November, Tokyo, 283-286.

Mark D.M., Smith B., Tversky B. (1999). *Ontology and geographic objects: an empirical study of cognitive categorization*. In: Freksa C., Mark D.M. (eds) *Spatial information theory: cognitive and computational foundations of geographic information science*. Springer, New York, pp 283–298

McCormack G., Giles-Corti B., Lange A., Smith T., Martin K., & Pikora, T.J. (2004). An update of recent evidence of the relationship between objective and self-report measures of the physical environment and physical activity behaviours. *Journal of Science and Medicine in Sport*, 7(1), 81–92.

Mitchell M. (2009). *Complexity. A guided tour*.

Montello D.R. (1991). Spatial orientation and the angularity of urban routes: a file study. *Environment & Behaviour*, 23, 47-69.

Montello D.R. (1992). *The geometry of environmental knowledge*. In: Frank A.U., Campari I., Formentini U. (eds) *Theories and methods of spatio-temporal reasoning in geographic space*. Springer, New York, pp 136–152.

Montello D.R. (2001). *Spatial Cognition*. In Smelser N.J., Baltes P.B. (eds). International Encyclopedia of the Social & Behavioral Sciences. Pergamon Press. Oxford. pp. 14771-14775.

Montello D.R., Freundschuh S. (2005). *Cognition of geographic information*. In: McMaster R.B., Usery E.L. (eds) *A research agenda for geographic information science*. CRC Press, Boca Raton, pp 61–91.

Montello D.R. (2016). *Behavioral Methods for Spatial Cognition Research*. In Gifford R. (Ed.), *Research Methods for Environmental Psychology*. Wiley Blackwell.

Morris W. (1891). *News from nowhere*. Reevers & Turner.

Nasir M., Lim C.P., Nahavandi S., Creighton D. (2014). A genetic fuzzy system to model pedestrian walking path in a built environment. *Simulation Modelling Practice and Theory*, 45, 18-34.

Ng C.F. (2016). *Behavioral Mapping and Tracking*. In Gifford R. (Ed.), *Research Methods for Environmental Psychology*. Wiley Blackwell.

Orland B., Daniel T. C., & Haider W. (1994). Calibrated images: Landscape visualizations to meet rigorous experimental design specification. In *Proceedings of Decision Support 2001*—Resource Technology 94. American Society for Photogrammetry and Remote Sensing (pp. 919–926), Washington, DC.

Ostwald M., Dawes M.: 2011, Axial line analysis revisited: reconsidering its value for architecture. *The international journal of the constructed environment*. 1(3) 219-242

Owen N., Cerin E., Leslie E., duToit L., Coffee N., Frank L.D., et al. (2007). Neighborhood walkability and the walking behavior of Australian adults. *American Journal of Preventive Medicine*, 33(5), 387–395.

Owen N., Humpel N., Leslie E., Bauman A., & Sallis J.F. (2004). Understanding environmental influences on walking; Review and research agenda. *American Journal of Preventive Medicine*, 27(1), 67–76.

Papadimitriou E., Yannis G., Golias J., A critical assessment of pedestrian behaviour models, *Transport. Res. Part F: Traffic Psychol. Behav.* 12 (3) (2009) 242–255.

M. Perdomo, A. Rezaei, Z. Patterson, N. Saunier, L.F. Miranda-Moreno (2014). Pedestrian preferences with respect to roundabouts – A video-based stated preference survey. *Accident Analysis and Prevention*, 70 (2014), pp. 84-91.

Piaget J., Inhelder B. (1956). *The child's concept of space*. Humanities Press, New York.

Portugali J. (2011). *Complexity, cognition and the city*. Springer.

Pugin A.W.N. (1836). *Contrasts: Or, A Parallel Between the Noble Edifices of the Fourteenth and Fifteenth Centuries and Similar Buildings of the Present Day. Shewing the Present Decay of Taste*. London: Charles Dolman.

Ruskin J. (1849). *The Seven Lamps of Architecture*. Smith, Elder & Co.

Sadalla E.K., Montello D.R. (1989). Remembering changes in direction. *Enviornment & Behavior*, 21, 346-363.

Shigematsu R., Sallis J.F., Conway T.L., Saelens B.E., Frank L.D., Cain K.L., et al. (2009). Age differences in the relation of perceived neighborhood environment to walking. *Medicine and Science in Sports and Exercise*, 41(2), 314–321.

Sitte C. (1945). *The Art of Building Cities: City Building According to Its Artistic Fundamentals*. Reinhold Publishing Corporation.

Sitte C. (1986). *City planning according to artistic principles*. Rizzoli, New York.

Sommer R., Sommer B. (2002). *Mapping and trace measure*. In: *A practical guide to behavioural research: tools and techniques*. Oxford University Press. New York.

Southworth M. (2003). Measuring the liveable city. *Built Environ* 29(4):343–354.

Stevens A., Coupe P. (1978). Distortions in judged spatial relations. *Cogn Psychol* 10(4):422–437.

Ståhle A., Marcus L., Karlström A. (2008). Place Syntax: Geographic accessibility with axial lines in GIS. *Proceedings in 5th Space Syntax Symposium*, Delft.

Taylor, Spehar, Van Donkelaar, Hagerhall (2011). Perceptual and Physiological Responses to Jackson Pollock's Fractals. *Frontier in Human Neuroscience*, Vol 5.

Terna P. (2015). *From Complexity to Agents and Their Models*. In: Boero, R., Morini, M., Sonnessa, M., Terna, P. (2015), *Agent-based Models of the Economy: From Theories to Applications*. Palgrave.

Tolman E.C. (1938). The determiners of behaviour at a choice point. *Psychological Review*, 45, 1-41.

Tolman E.C. (1948). Cognitive maps in rats and men. *Psychological Review* 55(4): 189-208.

Thomas I., Frankhauser P. (2013). Fractal dimensions of the built-up footprint: buildings versus roads. Fractal evidence from Antwerp (Belgium). *Environment and Planning B: Planning and Design*, volume 40, pages 310-329.

Trowbridge C.C. (1913). On fundamental methods of orientation and ‘imaginary maps’. *Science* 38 (990): 888-897.

Tveit M., Ode, Å., & Fry G. (2006). Key concepts in a framework for analysing visual landscape character. *Landscape Research*, 31(3), 229–255.

Tversky B (2003) Structures of mental spaces: how people think about space. Environ Behav 35(1):66–80

Van Dyck D., Cerin E., Conway T.L., De Bourdeaudhuij I., Owen N., Kerr J., et al. (2013). Perceived neighborhood environmental attributes associated with adults' leisure time physical activity: Findings from Belgium, Australia and the USA. *Health & Place*, 19, 59–68.

Wang Y., Chau C.K., Ngb W.Y., Leung T.M. (2016). A review on the effects of physical built environment attributes on enhancing walking and cycling activity levels within residential neighborhoods. *Cities*, Volume 50, February 2016, Pages 1–15.

Wardman M. (1988). A Comparison of Revealed Preference and Stated Preference Models of Travel Behaviour. *Journal of Transport Economics and Policy*, 22(1), 71-91.

Weiss R., Boutourline S. (1962). *Fairs. Exhibits. Pavilions and Their Audiences*.

Wilensky U., and Rand W. (2015). *An Introduction to Agent-Based Modelling*. MIT Press.

Wilson E.O. (1986). *Biophilia*. Harvard University Press.

Wilson E.O. (2004). *On Human Nature*. Harvard University Press.

Xi H., Son Y.-J., (2012). Two-level modeling framework for pedestrian route choice and walking behaviors, *Simul. Model. Pract. Theory* 22, 28–46.

Zacharias J. (2001). Pedestrian Behavior and Perception in Urban Walking Environments. *Journal of Planning Literature*, Vol. 16, n. 1.

Zube E. H., Sell J. L., & Taylor J. G. (1982). Landscape perception: Research, application and theory. *Landscape Planning*, 9(1), 1–33.