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THE IMPACT OF ARCHITECTURAL AND URBAN PATTERNS ON THE BEHAVIOUR OF AN EXHIBITED ANGULAR SIZE-ILLUSION

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INTRODUCTION

Contemporary architectural and urban practice requires a permanent connection to other edging professions such as psychology. This paper tries to reveal another specific nature of such a connection, continuing existent scientific studies in the field of architectural and environmental psychology (LeCompte and Yetken, 1975; McMillen, 1975; İmamoglu, 1976, 1986; Sunar and LeCompte, 1977) by trying to import more broadly the perceptual psychology knowledge into the architectural and urban planning science (and practice).

The law on perspective perception of three-dimensional spaces stipulates that as the observer moves towards the object of perception, it appears larger and vice-versa (Zdravkovic-Jovanovic, 1995). However, under some circumstances, as the distance changes, the impression of the perceived object's volume does not as described, but inversely. As it has already been confirmed by Djordjevic and Vujic (2010), this occurrence is based on the angular size-illusion influence, due to the impact of specific perceptual factors in the form of distance-depth cues and specific neural activities (Murray et al., 2006). This includes an additional influence of another perceptual factor known as the oculomotor micropsia (McCready, 1965; Komoda and Ono, 1974; Ono et al., 1974).

This paper continues the research performed by Djordjevic and Vujic (2010), by exploring the impact of various architectural and urban patterns on the behavior of an angular size-illusion noticeable during the observer's continual and uniform movement. It can be understood as a specific case-study in the field of architecture and urbanism that attempts to explore parameters assumed both as proper illusion quantifiers and qualifiers (such as: descriptors and determinants). The defined valorization criteria allow the methodological investigation of the influences of those determinants on the descriptor's behavior by analyzing the illusion quantifier's conduct.

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Considering the possible applications of such a visual illusion in contemporary architectural and urban practice, by investigating its core specificity, it will be possible to set up the illusion in advance. So, by planning adequate spatial interventions either on existing or newly designed/reconstructed architectural and urban locations, the illusion's behavior could be estimated and controlled with precision in reality. Thus, it would be possible to minimize any inappropriate usage, that is, to annul any potential reasons that may cause unwanted or unpredictable visual impression degradations of important architectural and urban structures.

The research by Abu-Obeid and Abu-Safieh (2010) could reversely help redefine (from the subject-related point of view) both a proper movement-path geometry and its morphologically and volumetrically adequate architectural and urban surrounding. Also the study by Lee et al. (2015) enables a better understanding of how the built environment (or one in draft), consisting of concrete (or planned) architectural and urban elements, can affect the observer's visual attention mechanism (with or without the influence of additional educational training) and, thus, the selection of spatial entities which will be recognized as relevant visual markers (crucial to trigger the angular size-illusion).

Also, it becomes possible now to confirm the estimated behavior of an angular size-illusion-to-be in reality (as the observer moves throughout a concrete either new or reconstructed architectural and urban pattern), by using various virtual-reality systems (such as driving simulators: Maghelal et al., 2011).

PREVIOUS SUBJECT-RELATED RESEARCH

Numerous studies in optics, neurophysiology and psychology have investigated the occurrence of the visual illusions as a whole to reveal sustainable fundamentals that will explain when, why and how the visual sensory system alters the reading of existing characteristics of observed planar and spatial elements; primarily their size/volume, shape, color and location.

The visual illusions being based on visual perception characterized by a paradoxical perceptive evaluation of mentioned features, most attempts at defining those illusions were founded on the implementation of the so-called Apparent Distance Theory, namely its classical SDIH-hypothesis (Size-Distance Invariance Hypothesis) (Kilpatrick and Ittelson, 1953).

However, the scientific results thereof were hardly satisfactory because they excluded important influences of the foregoing perceptual factors and neurophysiologic influences. Hence, as the perception of "linear sizes/distances", except for monocular and binocular facts, is actually influenced by numerous contextual/surrounding signals (such as distance/depth cues), which actually determine the perception of their visual angles, the research of these impacts led to a more comprehensive explanation of those inter-dependences (Rock and McDermott, 1964; Restle, 1970). This modified perceptual view was the origin of the altered so-called "new SDIH hypothesis" (New Perceptual Size-Distance Invariance Hypothesis) (McCready, 1985; 1986).

Generally, such an approach comes as a consequence of the visual angles of target's perception being, actually, its perceived visual angles (Baird, 1970; Higashiyama, 1992), relevant for the simultaneous perception of target's linear sizes (specifically its perceived linear sizes) from the absolute distances (Colheart, 1970) as well as from the perceived distances (Hastorf, 1950; Roscoe, 1984) - under the influence of distance/depth cues (Bolles and Bailey, 1956; Komoda and Ono, 1974; Higashiyama and Shimono, 1994; McCready, 1985; Gogel and Eby, 1997). Such target's perception as a perception of its visual angles (defined by pairs of eye-rays which correspond to the endpoints of the perceived linear sizes) is also deeply investigated by Foley (1980) ("Direction-Perception", "Egocentric Distance-Signal Perception") and Murray et al. (2006) ("Neurophysiologic Approach").

Hence, the elaborated "Size illusions" actually are "Visual angle illusions" that is "Angular size illusions".

One subject-related research was also performed in the architectural and urban field. It confirmed that the paradoxical visual effect related to a seeming size-decrease of architectural and urban objects - noticeable as the observer approaches them, can be treated as the consequence of this angular size-illusion influence. The fundamentals of that illusion were investigated once it appeared in built spaces, together with specific triggering conditions and other relevant descriptors (Djordjevic and Vujic, 2010).

But the complexity of the occurrence of such a visual illusion requires in-depth exploration of the behavioral characteristics in order to understand it better and to professionally control its usage in architectural and urban practice.

Accordingly, this paper explores the impact of various architectural and urban patterns on the behavioral characteristics of an angular size-illusion, noticeable during movement- keeping invariant both the path geometry and the focused/targeted object of interest.

RESEARCH METHODOLOGY

Starting Considerations

To formulate scientifically sustainable conclusions, several starting terms, definitions and assumptions are introduced.

Because of the nature of this research, starting terms and their meanings are inherited from the already mentioned subject-related research performed by Djordjevic and Vujic (2010):

- Focus, signed with letter F (hereinafter: focus), is an architectural or urban object, focused/targeted as an actual observer's subject of interest,
- Visual marker, signed with letter R (hereinafter: marker), is a referential but, often, a variable category, which, in a visually competitive relation with respect to the focus, makes the illusion possible during movement (**1**).

The following two parameters are assumed and defined as relevant illusion quantifiers:

- Δ-quantifier,
- Ψ-quantifier.

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1. Visual marker is to be declared as a variable category because the focus's physical surroundings unavoidably changes during the observer's movement.

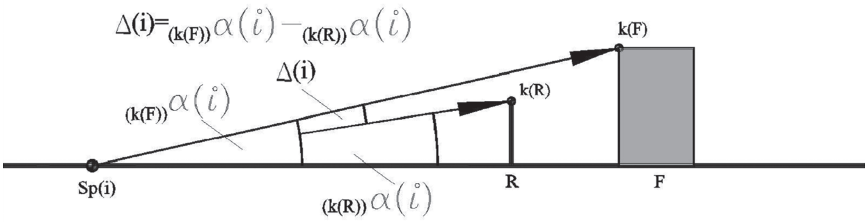


Figure 1. Graphic meaning of the illusion Δ-quantifier (Δ (i)). Each separate value is defined as the difference between visual angles under which a relevant pair of heights of the corresponding marker's and focus's contour-points (k(R) and. k (F)) is simultaneously perceived from the same station-point (Sp (i)).

There are two starting points:

- The perceived linear-sizes can be represented by their corresponding perceived visual angles, namely their angular sizes (foregoing Visual Size-Illusion Theory, that is Angular Size-Illusion Theory),
- The variations of perceived spatial interrelations between the marker's and the focus's linear sizes (noticeable as the observer moves towards the focus) refer to the seeming-change of the perceived focus's (x, y, z) dimensions with respect to those of the marker.

Consistent with the above, it can be concluded that mentioned variations ought to be valorized comparing the relevant angular sizes as the perceptual equivalents of those perceived dimensions. But, notwithstanding that the latter conclusion relates to a seeming-change of the focus's and the marker's volumes as a whole, for a more comprehensive elaboration, that seeming-change analysis will be limited to their heights only (defined by spatial positions of the focus's and the marker's upper contour-lines).

Consequently, such an analysis will use the visual delta inclination-angles (Δ(i)), whose values are defined as the differences between visual angles under which relevant pairs of heights of the corresponding marker's and focus's upper contour-points (marked as k(R) and k(F)) are simultaneously perceived from the same observer's position (station-point Sp(i)) (**Figure 1**). According to the graphic representation of that delta-angle, it can be calculated, as: $\Delta\ (i) = {}_{(k\ (F))}\ \alpha\ (i)\ -\ {}_{(k(R))}\ \alpha\ (i)$.

Degree stands for the chosen unit of Δ-values. Since this dimensional seeming-change is a core explanatory mechanism of the subject-related illusion which can metrically be captured by using the described delta-angle, this delta-angle is assumed to be a relevant illusion quantifier (hereinafter: Δ-quantifier).

Following the Δ-quantifier's meaning, its positive (+) values demonstrate that the focus's upper contour-line points are perceived as higher than those of the marker, while its negative (-) values show the opposite. Consequently, the zero-values of the Δ-quantifier demonstrate that the corresponding marker's and focus's heights are perceived as mutually identical from a concrete station-point (so that each related pair of focused upper contour-line points seemingly mutually overlap).

The other illusion quantifier (Ψ-quantifier) will be presented later on.

Besides the quantifiers, it is necessary to formulate the descriptors and the determinants assumed to qualify the illusion's behavioral characteristics.

Five illusion descriptors are defined:

- Noticeability,
- Appearance,
- Duration,
- Dynamics,
- Overall impression.

Illusion noticeability describes its state of being seen as the marker-to-focus dimensional seeming-change impression, as a consequence of both the observer's movement and the presence of relevant triggering conditions (Djordjevic and Vujic, 2010).

Illusion appearance describes its state of becoming noticeable.

Illusion duration describes the persistence of illusion noticeability over time. Besides this temporal approach, the term duration can also be metrically redefined: either by the function of a concrete path-segment's length that the illusion is noticeable from, or, equivalently, by the function of a total number of station-points uniformly distributed on that path-segment.

Consistent with: (a) the fundamental meaning of the term dynamics (describing it as a changing rate or variation level between two neighboring values of the same nature, divided by the elapsed time of that variation) and (b) that the subject-related illusion implies the appearance (and certain duration) of the marker-to-focus dimensional seeming-change impression, an illusion dynamics is to be assumed as the third relevant illusion descriptor. Thus, because such an impression is a result of the imminent comparison of each of the two consecutive values of the corresponding Δ-quantifiers (Δ (i+1) and Δ (i)) which refer to a pair of neighboring station-points (to a concrete period of movement-time), the illusion dynamics descriptor is seen as adequate to express that impression's changing rate in a most natural way. To properly measure the changing behavior of this impression in time, the Ψ-quantifier is defined as an appropriate gauge of the illusion dynamics-flow.

Accordingly, the Ψ-quantifier's value describes the level of the Δ-quantifier's variation divided by the elapsed time of that variation. Also, given the non-temporal viewpoint, the Ψ-quantifier's value can be reformulated metrically - as a value of the Δ-quantifier's variation - divided by the distance between station-points that correspond to this variation. As the station-point inter-distances are set as invariant in this research, the distance value of one unit (one meter/inch) is assigned to them, so that the value of each separate Ψ-quantifier can be expressed as:
$\Psi((i+1)\rightarrow i) = (\Delta(i+1) - \Delta(i)) / 1 = \Delta(i+1) - \Delta(i)$.

Degree/meter-inch stands for the Ψ-quantifier's chosen unit. Hence, it is obvious that the higher the Ψ-quantifier's value, the more evident the Δ-quantifier's changing rate (and, thus, the dynamics of the illusion, namely of the marker-to-focus dimensional seeming-change impression) during movement or, more precisely, in the corresponding sequence of movement-time.

Following the Ψ-quantifier's meaning, its positive (+) value demonstrates that the Δ-quantifier's value, referring to the subsequent station-point (located closer to the marker/focus), is higher than that related to its preceding station-point (located farther away from the marker/focus) and vice-versa. Consequently, the zero-value of the Ψ-quantifier indicates that the values of two consecutive Δ-quantifiers are the same.

Overall impression (more precisely, the overall dimensional seeming-change impression) describes the overall difference between the values of ending and starting angular differences between the marker's and the focus's heights (expressing actually how much the focus has totally sunk with regard to its marker as the observer finally reaches both of them). This parameter is calculated as the difference between the ending/final and starting Δ-qualifier's values of the corresponding illusion.

Apart from the investigated impact of the markers and their role in the subject-related illusion (Djordevic and Vujic, 2010), this research presumes also that the following factors, formulated as illusion determinants, might play an important role in determining the illusion's behavioral characteristics.

These illusion determinants are:

- Inclination of the observer's movement-path,
- Metric difference between the actual heights of the marker and focus (namely their upper contour-lines).

Selection of Architectural and Urban Examples

Given the conditions required to trigger the subject-related illusion (Djordjevic and Vujic, 2010), several architectural and urban locations in Belgrade (Serbia) are considered. To explore the influence of the defined illusion-determinants on the established descriptors' behavior, three architectural and urban pattern configurations are chosen as representative examples (hereinafter: RE's) because of their specificities in a morphological sense:

- RE-1: a horizontal part of Kralja Milana Street - from Kneza Milosa Street to Slavija Square,
- RE-2: a declined part of Resavska Street - from Krunska Street to Kralja Aleksandra Boulevard, and
- RE-3: an inclined part of Tirsova Street - from Kneza Milosa Street to Sarajevska Street.

Geometry-wise, all chosen movement-paths are straight.

Each horizontal photo-strip on **Figure 2** shows a characteristic triptych of shots ((a), (b) and (c)) that refer to each of the representative locations listed above (RE-1, RE-2 and RE-3).

In the first triptych - related to example RE-1, the focus F is St. Sava Temple (a distant, centrally-positioned object); the perceived marker's volume is defined by the surrounding buildings and vegetation - visually competitive with respect to the focus (**Figure 2.1** ((a), (b), (c)). The marker's volume parts of a built nature consist of visually dominant left- and right-side architectural objects (represented by the Old and New Slavija Hotels). Because the height of the right-side marker's part (the height of the New Slavija Hotel) is clearly visible from each of the three chosen station-points (contrary to the left-side one), that marker's part (marked as R) is the chosen reference.

In example RE-2, the focus F is St. Marko Church (a distant, centrally-positioned object); the perceived marker's volume is defined by the

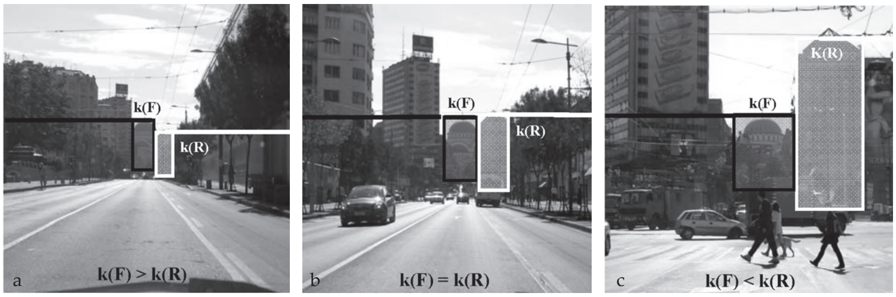


Figure 2.1.

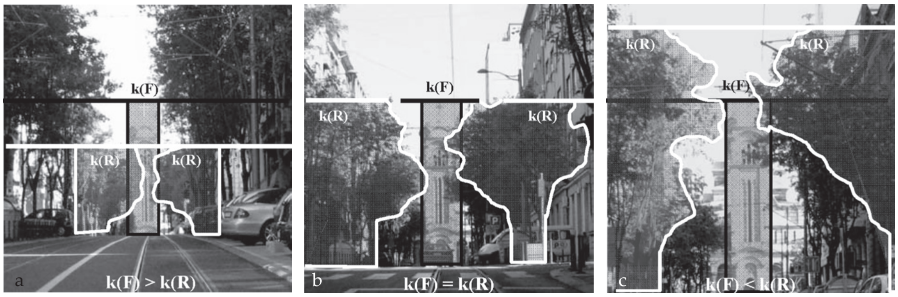


Figure 2.2.

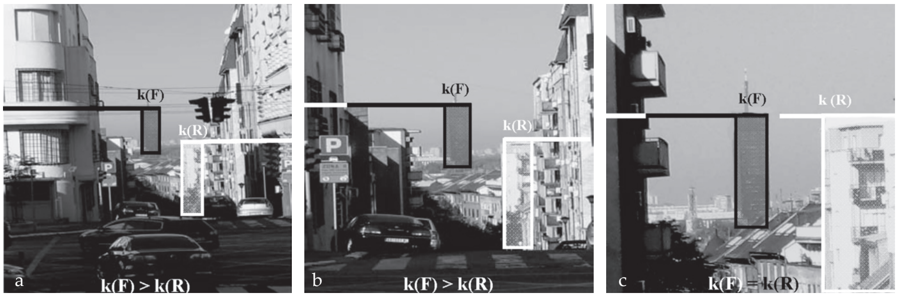


Figure 2.3.

Figure 2 (Figures 2.1, **2.2** and **2.3**.) The three horizontal photo-strips (one for each location/representative example chosen), created to illustrate the occurrence of the angular size illusion noticeable during the observer's movement towards the corresponding foci F - as an evident dimensional seeming-change impression between their heights and those of the corresponding markers R: RE-1- with straight horizontal path (**Figure 2.1** ((a),(b),(c)); RE-2 - with straight path, inclined away from the corresponding marker/focus that is declined (**Figure 2.2** ((a),(b),(c)), and RE-3 - with straight path, inclined towards the corresponding marker/focus (**Figure 2.3** ((a),(b),(c)).

surrounding vegetation only- visually competitive with respect to the focus (**Figure 2.2** ((a), (b), (c)). Both the left and the right-side marker's parts, represented by a group of neighboring trees (and marked as R) are the chosen references.

In example RE-3, the focus F is Usce Palace (a distant, centrally-positioned object); the perceived marker's volume is defined by its drastically closer surrounding objects- visually competitive with respect to the focus (**Figure 2.3** ((a), (b), (c)). The right-side part of the perceived marker's volume, represented by the distant, right-positioned object (marked as R) is the chosen reference.

So, each horizontal photo-strip consists of three non-consecutive photographs of the same location, captured from station-points mutually distant enough to comprehensively demonstrate the occurrence of this visual illusion to a third-party who has not experienced this illusion yet.

Respecting those shooting criteria, photographs that belong to the same photo-strip are taken from station-points located:

- At the far end of the corresponding foci, when they are seemingly perceived as higher than their markers: (examples RE-1, RE-2 and RE-3) –**Figure 2.1** (a), **Figure 2.2** (a) and **Figure 2.3** (a),
- Closer to the corresponding foci, when they either catch up in height with the markers (examples RE-1 and RE-2) or when the

focus remains seemingly perceived as higher than its marker (example RE-3) – **Figure 2.1** (b), **Figure 2.2** (b) and **Figure 2.3** (b),

- At the closest to the corresponding foci, when they are seemingly perceived as lower than their markers (examples RE-1 and RE-2) or when the focus catches up in height with its marker (example RE-3) – **Figure 2.1** (c), **Figure 2.2** (c) and **Figure 2.3** (c).

Experimental Models Setup: Architectural and Urban Patterns Simplification

To obtain unambiguous results acceptable for evaluation, the chosen architectural and urban patterns are remodeled in an identical manner. This means that the complex real geometry of all focus's and marker's constituents is simplified so that their models contain only the spatial elements that make the illusion simulation sustainable and fundamentally conform to the illusion triggered in reality. By using the experimental models (hereinafter: EM's), it is possible to explore the relevant behavioral characteristics of each simulated illusion.

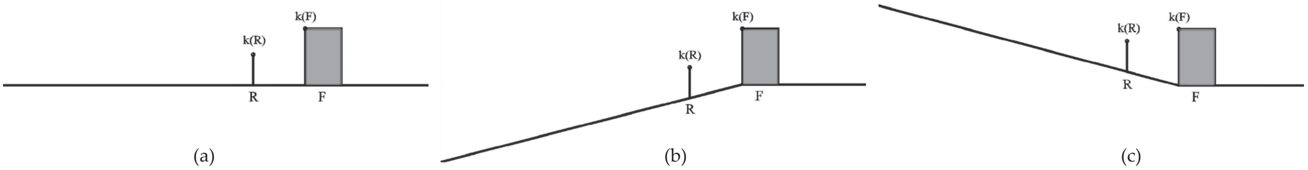
According to Djordjevic and Vujic (2010), this remodeling implies that:

- The mass of the focus F is simplified by a vertical quadrangular-base prism,
- The mass of the marker R is simplified by its compression to 2D, so that it is represented by two separated, identical, vertical rectangles positioned in the same depth-plane and with their own upper (horizontal) rims at the same height (so that the rims be mutually collinear); the rectangles' common (depth) plane is parallel to the frontal plane of the focus prism and located in front of it; these rectangles are positioned symmetrically with regard to an imaginary vertical plane of the focus's longitudinal symmetry (**2**),
- The movement-path is simplified to be straight; its real spatial position is corrected to be in the imaginary focus's longitudinal symmetry-plane.

Consequently, three fundamental experimental models are created from examples RE-1, RE-2, and RE-3:

- Model EM-1 - with a horizontal straight movement-path (**Figure 3** (**a**)),
- Model EM-2 - with a declined straight movement-path, inclined away from the corresponding marker/focus (**Figure 3** (b)),
- Model EM-3 - with a straight movement-path, inclined towards the corresponding marker/focus (**Figure 3** (c)).

To obtain sustainable conclusions, in each model (along the corresponding path), 11 station-points are located on the same side of the marker/focus so as to be mutually equidistant. Dimensional and spatial marker-to-focus



(a) (b) (c)

Figure 3. Longitudinal sections of three fundamental models with simplified patterns that morphologically correspond to examples RE-1, RE-2 and RE-3 – models: EM-1 (a), EM-2 (b), and EM-3 (c) (graphic elements F and R represent the real masses of corresponding foci and markers, while k (F) and k(R) are graphic representations of their horizontal upper contour-lines).

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2. Frontally means vertically and perpendicularly to an imaginary vertical plane of the focus's longitudinal symmetry; directed at the starting position of the observer's movement.

(a) (b)

Figure 4. Longitudinal sections of two sub-models, additionally defined with slight modifications of the fundamental model EM-1 - sub-models: EM-1/a (a) and EM-1/b (b).

interrelations, including entire movement-path lengths, don't strictly match real ones.

Also, two additional sub-patterns (where the marker's heights are either equal to or larger than those of their foci) have to be investigated because of their frequent presence in reality (**Figure 4**).

Although these sub-patterns can be seen in all selected examples, to retain simplicity, the marker's 'height-influence' on the exhibited illusion behavior will be discussed under the fundamental example RE-1 only (with a horizontal movement-path). Thus, two additional sub-models are created with slight modifications of that fundamental model:

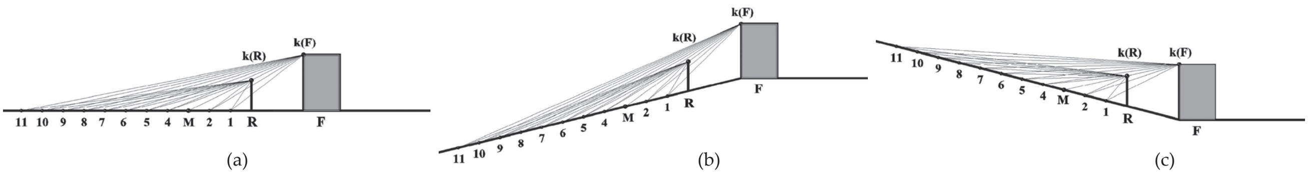
- EM-1/a - where the heights of the marker and the focus are equal (**Figure 4** (a)),
- EM-1/b - where the marker is higher than the focus (**Figure 4** (b)).

OUTPUT DATA ACQUISITION AND PRESENTATION

Raw experimental outputs are values of relevant pairs of visual angles that capture the heights of the corresponding perceived marker's and focus's upper contour-line points (related to each example separately). These angles are acquired by angular measurements performed directly on their graphic (CAAD) representations (**Figure 5**, **Figure 6**).

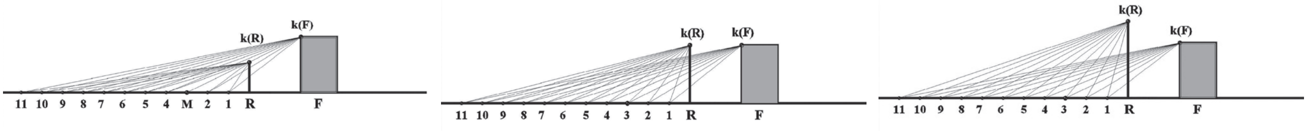
Processed experimental outputs are the values of two illusion quantifiers (Δ and Ψ), obtained and calculated for each example - respecting their fundamental meanings. Then, the quantifier's values so calculated (of both types) are organized into tables and presented in charts in the form of trend-lines.

Figure 5 represents the longitudinal sections of three fundamental models: EM-1 (a), EM-2 (b), and EM-3 (c), together with the relevant pairs of visual angles that (from each concrete station-point Sp(i) (i=1,11)) capture the heights of the corresponding markers' and foci's upper contour-line points (k(R) and k (F)).



(a) (b) (c)

Figure 5. Longitudinal sections of three fundamental models, together with the relevant pairs of visual angles (and, indirectly, corresponding Δ–quantifiers), related to each defined station-point: EM-1 (a), EM-2 (b), and EM-3 (c).



(a) (b) (c)

Figure 6. Longitudinal sections of the fundamental model and its sub-models, together with the relevant pairs of visual angles (and, indirectly, corresponding Δ–quantifiers), related to each defined station-point: EM-1 (a) and EM-1/a (b), EM-1/b (c).

Δ-quantifier values (deg)		Station-points along the corresponding movement-paths										
		11	10	9	8	7	6	5	4	3	2	1
Models/ sub- models created	‘EM-1’	+1.507	+1.832	+1.036	+0.621	**0.000**	-0.950	-2.448	-4.916	-9.247	-17.846	-34.356
	‘EM-2’	+3.239	+3.330	+3.402	+3.435	+3.397	+3.228	+2.812	+1.912	**0.000**	-4.212	-14.09
	‘EM-3’	+3.802	+3.963	+4.113	+4.234	+4.286	+4.192	+3.787	+2.698	**0.000**	-6.783	-23.57
	‘EM-1/a’	-2.510	-2.954	-3.525	-4.274	-5.280	-6.668	-8.641	-11.54	-15.91	-22.51	-31.86
	‘EM-1/b’	-7.578	-8.436	-9.481	-10.77	-12.39	-14.47	-17.15	-0.66	-25.21	-30.88	-37.17

Table 1. Δ-quantifier values related to corresponding models/sub-models: EM-1, EM-2, EM-3, EM-1/a and EM-1/b.

Ψ-quantifier values (deg/m)		Segments of movement-paths defined between every two successive station-points									
		11→10	10→9	9→8	8→7	7→6	6→5	5→4	4→3	3→2	2→1
Models/ sub- models created	‘EM-1’	-0.326	+0.796	+0.415	+0.621	-0.950	-1.498	-2.468	-4.331	-8.599	-16.510
	‘EM-2’	-0.091	-0.072	-0.033	+0.038	+0.169	+0.416	+0.900	+1.912	-4.212	-9.878
	‘EM-3’	-0.161	-0.150	-0.121	+0.052	+0.094	+0.405	+1.089	+2.698	-6.783	-16.697
	‘EM-1/a’	-0.444	-0.570	-0.749	-1.006	-1.388	-1.973	-2.899	-4.370	-6.600	-9.350
	‘EM-1/b’	-0.858	-1.045	-1.292	-1.623	-2.070	-2.685	-3.505	-4.551	-5.671	-6.290

Table 2. Ψ-quantifier values related to corresponding models/sub-models: EM-1, EM-2, EM-3, EM-1/a and EM-1/b.

Figure 6 represents the longitudinal sections of the model EM-1 (a) and its two sub-models:
EM-1/a (b) and EM-1/b (c), together with the relevant pairs of corresponding visual angles.

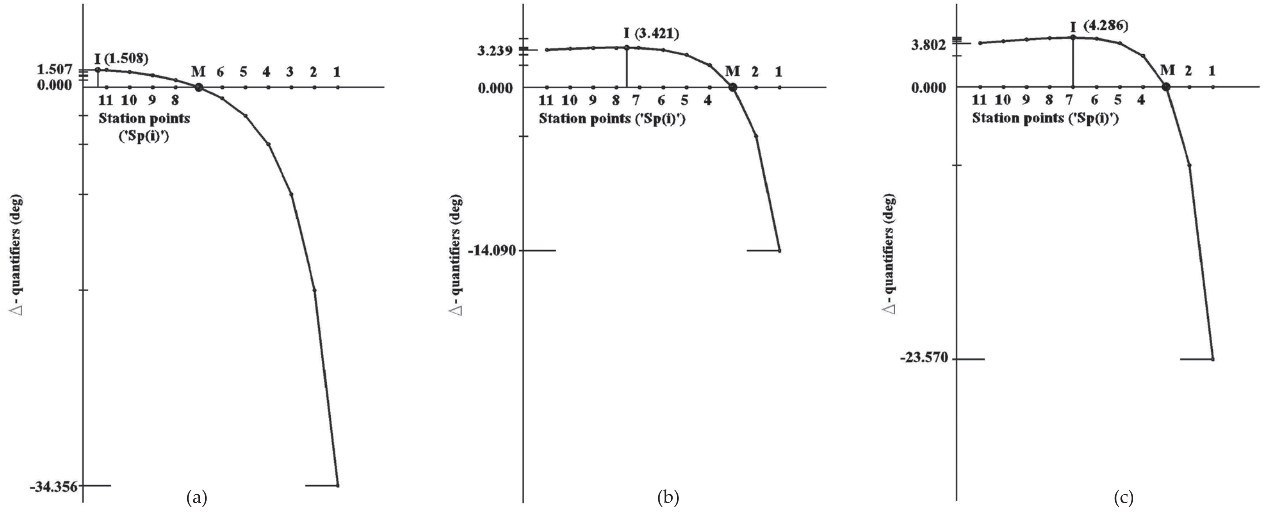
Table 1 shows the Δ-quantifier's values (Δ (i) (i=1, 11)), calculated for each concrete station-point (Sp(i)), located on movement-paths that belong to five corresponding models/sub-models: EM-1, EM-2, EM-3, EM-1/a and EM-1/b.

Table 2 shows the Ψ-quantifier's values (Ψ((i+1)→(i)) (i=1,10)), calculated for every two successive station-points (Sp(i+1) and Sp(i)), located on the movement-paths that belong to those models/sub-models.

DISCUSSION

General Behavior of an Angular Size-Illusion Exhibited Under the Influence of the Established Determinants

To study how the movement-path inclination determines the subject-related illusion behavior in general, a set of defined models are used: EM-1, EM-2 and EM-3.



(a) (b) (c)

Figure 7. General behavior of an angular size illusion, noticeable during the movement throughout architectural and urban patterns represented by the models: EM-1 (a), EM-2 (b), and EM-3 (c).

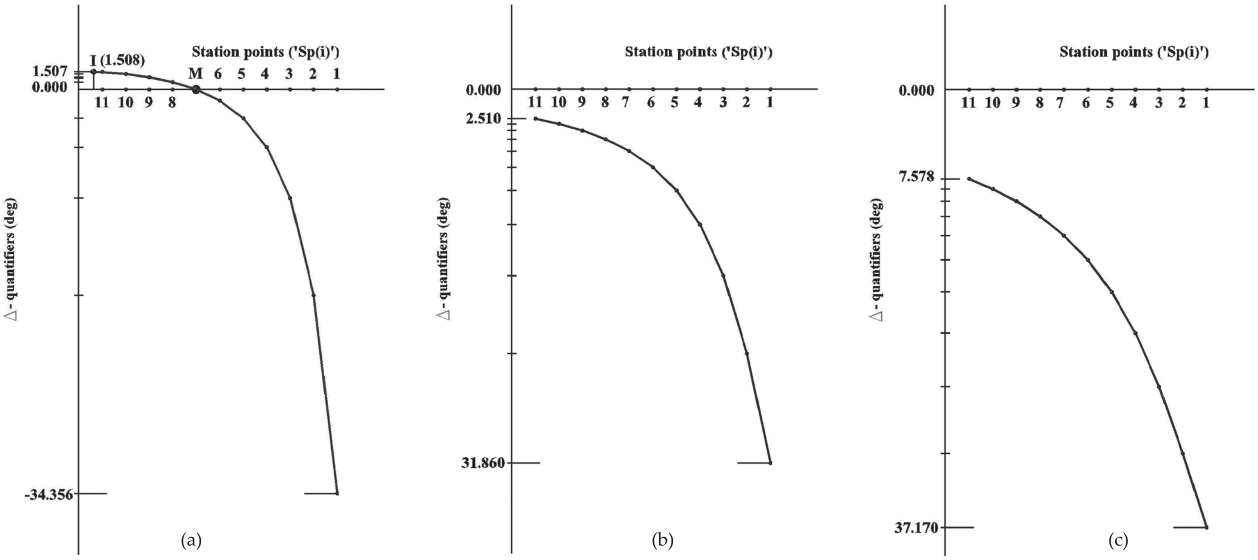


Figure 8. General behavior of an angular size illusion, noticeable during the movement throughout architectural and urban patterns represented by the model EM-1 (a) and its two sub-models: EM-1/a (b), and EM-1/b (c).

To study how the difference in height of both the marker and the focus determines the general behavior of that illusion, the model EM-1 and its sub-models: EM-1/a and EM-1/b are used.

Based on the data in **Table 1**, trend-lines on **Figure 7** and **Figure 8** are created.

These trend-lines indicate the general behavioral characteristics of the exhibited illusion (for each example used), obtained under the influence of the established determinants, through flow-characteristics of the corresponding Δ-quantifiers (in the function of each defined station-point).

Common Remarks

By analyzing the trend-lines on **Figure 7** and **Figure 8,** it can be observed that the level of the trend-line inclination clearly shows how rapidly the Δ-quantifier's values change over the illusion duration and, thus (according to the Δ-quantifier's meaning), how impressive the actual marker-to-focus dimensional seeming-change is (the steeper the trend-line, the more noticeable the illusion). Additionally, the presence of slight trend-line peaks in some examples (marked as I) shows that there are sets of consecutive Δ-quantifiers with the same (or almost the same) values that relate to those peaks and their very close neighboring trend-line points, implying that there is no dimensional seeming-change impression present (or that it is infinitely small) **(3).** To put it otherwise, if the trend-line peak exists, the illusion is not present (or its noticeability is poor) during the perception from the path-segments that correspond to that Δ-quantifier's peak value and its close surroundings.

Regarding the meaning of positive/negative Δ-quantifier's values, the parts of the trend-lines located above their abscissas, show segments of the corresponding movement-paths from which the foci are perceived as higher than the corresponding markers (and vice-versa). When there are intersection points of trend-lines and their abscissas (marked as M), from the station-points related to those intersections, the heights of the perceived foci seemingly catch up the heights of the corresponding markers (they become perceived as if mutually overlapping). Thus, the point M can be

3. Trend-line peak is its point with horizontal or almost horizontal tangent, parallel to the chart's abscissa.

treated as a specific- involuntary station-point after which a seemingly higher focus with respect to its marker becomes perceived as lower than that of the marker (as the observer approaches both).

As expected, due to the established prerequisites that: (i) the observer's movement ought to be uniformly performed along a continual straight path, and (ii) the marker is to be invariant during that movement (Djordjevic and Vujic, 2010)- geometry-wise, all trend-lines on **Figure 7** and **Figure 8** are similar. Namely, they are continual and smooth, characterizing thus a continual and uniform marker-to-focus dimensional seeming-change impression (through a permanent and uniform seeming fall, namely the sinking of the perceived foci's heights with respect to those of their markers). This tendency is noticeable over the entire duration of each exhibited illusion.

By comparing the trend-lines on **Figure 7**, besides their common characteristics underlined above, there are some slight differences between them (and, consequently, in the general behavior of the illusion they relate to). In contrast, the trend-lines on **Figure 8** are characterized by an evident mutual difference (pointing to some important behavioral specificities of the corresponding illusions).

Specific Remarks

A differential analysis of the trend-lines on **Figure 7** shows that only in the model EM-1, during the initial movement (from starting station-points 11 towards the corresponding markers/foci), does its trend-line (**Figure 7** (a)) immediately but slightly incline, while in the other two examples, the corresponding trend-lines (**Figure 7** ((b), (c)) become less inclined. But, due to slight inclinations (that are also mutually similar), each of these less-inclined starting segments can be treated as almost horizontal.

According to the actual positions of trend-lines' peaks I, in the model EM-1, the illusion is noticeable from the very beginning of the movement-path (the corresponding peak refers to the station-point that is slightly away from the starting position 11). In the other two examples, the illusion noticeability is poor, even non-existent during the perception from the starting station-points that belong to 11 to 7 path-segments (because both of the corresponding peaks approximately relate to station-points 7). Thus, such a poor starting illusion noticeability (related to the models EM-2 and EM-3) is persistent during the perception from path-segments whose lengths are almost the same; approximately the starting 4/10 of the entire movement-paths lengths.

As the observer moves from the positions that relate to the analyzed peaks I towards the corresponding involuntary station-points M, according to trend-lines inclinations, the situation is as follows: in the model EM-1, the trend-line segment I to M is very shallow, it is steeper in the model EM-2 and it is the steepest in the model EM-3. So (during the perception from those paths segments), the starting seeming fall of the foci's heights, with respect to those of their markers, is the most noticeable in the model EM-3, less noticeable in the model EM-2 and, finally, the least noticeable in the model EM-1.

In all three examples, as the observer keeps moving in the same direction (from the involuntary station-points M to the end of the paths), the foci become perceivably lower than the markers. Also, the foci maintain a sinking tendency that (regarding drastically increased trend-lines inclinations) becomes more and more impressive as the observer approaches them. So, when he is about to reach the corresponding markers/foci, the most noticeable (and nearly mutually identical) seeming fall is seen in the models EM-2 and EM-3 while, in the model EM-1, that fall is slightly less noticeable.

Regarding the starting/ending Δ-quantifier's values, the highest overall impression is in the model EM-1: 32.849 deg, smaller in the model EM-3: 19.768 deg, and the smallest in the model EM-2: 10.851 deg.

A differential analysis of the trend-lines on **Figure 8,** shows that the main trend-line behavioral characteristics referring to sub-models EM-1/a (**Figure 8** (b)) and EM-1/b (**Figure 8** (c)) are mutually similar but significantly different from those related to the model EM-1 (**Figure 8** (a)). These differential characteristics of these sub-models are: (i) the absence of both the peak-point I and the involuntary station-point M, and (ii) the presence of negative Δ-quantifier's values only. The absence of peaks shows that the duration of the corresponding illusions is a characteristic of the perception obtained from the entire movement-paths (**4**). The absence of the involuntary station-points M and the presence of exclusively negative values of Δ-quantifiers, show that, from all station-points, the heights of the corresponding foci are always perceivable as smaller than those of the markers (**5**).

The trend-line behavioral characteristics that refer to the model EM-1 have already been elaborated (see: **Figure 7** (a) = **Figure 8** (a)).

By comparing the inclinations of all analyzed trend-lines, the first (referring to the model EM-1) is the highest; the sub-model EM-1/a is characterized by a smaller inclination, while in the sub-model EM-1/b, the trend-line is the least abrupt (but insignificantly lesser than in another sub-example). Thus, the seeming fall of the foci's heights with respect to those of the corresponding markers is more impressive in the model EM-1 than it is in both sub-models (where such impressions can be treated as almost identical).

Regarding the starting/ending Δ-quantifier's values, the highest overall impression is in the model EM-1: 32.849 deg, smaller in its sub-model EM-1/b: 29.592 deg, and the smallest in sub-model EM-1/a: 29.350 deg.

General Conclusions

Irrespective of whether the movement-path is horizontal, inclined towards the marker/focus or declined, for the defined experimental pre-sets, the behavioral characteristics of the exhibited illusion are almost the same. Thus, in all analyzed cases, the dimensional seeming fall of the focus's height with respect to that of the marker is continual and smooth, as the observer constantly and uniformly approaches both of them. The illusion is persistent along the entire movement-path only when it is horizontal, while the illusion duration is shorter on non-horizontal paths (when it lasts through the ending paths segments whose lengths are approximately 0.6 of the entire paths lengths). In all these cases, from the beginning of the illusion appearance, the dimensional seeming fall of the focus is the most impressive/noticeable for the declined path, then for the inclined and, finally, for the horizontal path. As the observer keeps moving in the same direction (towards the corresponding markers/foci), in all these cases such a falling impression becomes significantly noticeable and almost mutually identical. When the observer is about to reach the focus, the illusion

4. Considering that in the model EM-1, the peak I is positioned at the far end of the corresponding movement-path, its presence can be declared as insignificant; hence, from a duration viewpoint, this illusion doesn't differ from those related to sub-models.

5. Contrary to analyzed sub-models, the existence of the involuntary station-point M in the model EM-1, shows that observing from that involuntary point, the observer gets the impression that the height of the focus has finally succeeded in catching up seemingly the height of its marker. Also, such a sinking tendency is existent up to the end of the movement, due to negative values of Δ-quantifiers related to the ending (M to I) path-segment.

assumes its most dramatic character: first for the horizontal movement-path, then for the declined and, finally, for the inclined path. The overall impression of the focus's sinking with regard to its marker (known when the observer finally ended his movement) is the highest for the horizontal movement-path, smaller for the inclined, and the smallest for the declined path.

On the other side, notwithstanding the markers' heights with respect to those of the foci, for the defined experimental pre-sets, the exhibited illusion is persistent along the entire corresponding movement-paths. Also, for all analyzed interrelations of marker-to-focus heights, the existent dimensional seeming-change is also continual and smooth as the observer constantly and uniformly approaches both.

From the very beginning of the movement, the illusion noticeability is the largest when the marker is lower than the focus, lesser when their heights are equal in reality and, finally, the smallest when the marker is higher than the focus.

As the observer keeps moving in the same direction (towards the corresponding markers/foci), the illusion noticeability significantly increases; the illusion is the most noticeable when the marker is lower than the focus and less noticeable (but mutually almost identical) in the other two cases.

The overall impression of the focus's sinking with regard to its marker (known when the observer finally ends his movement) is the highest when the marker is lower than the focus, then when the height of the marker is greater and, finally, when their heights are equal.

Dynamics of an Angular Size-Illusion Exhibited Under the Influence of the Established Determinants

To study the impact of both established determinants on the dynamics characteristics of the exhibited illusion, the same sets of models/sub-models as those in the previous section are used.

Based on the data in **Table 2**, the trend-lines on **Figure 9** and **Figure 10** are created.

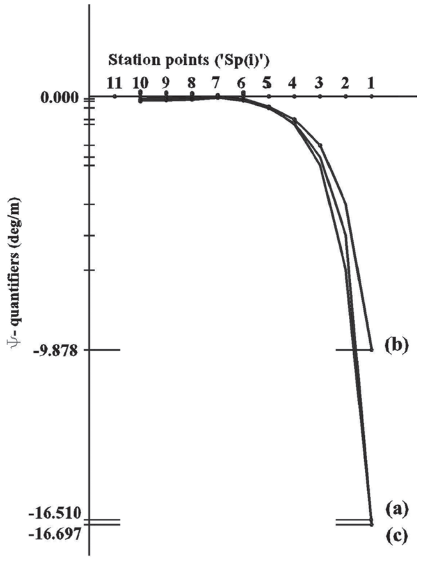


Figure 9. Dynamics of an angular size illusion, noticeable during the movement throughout architectural and urban patterns represented by the models: EM-1 (trend-line (a)), EM-2 (trend-line (b)), and EM-3 (trend-line (c)).

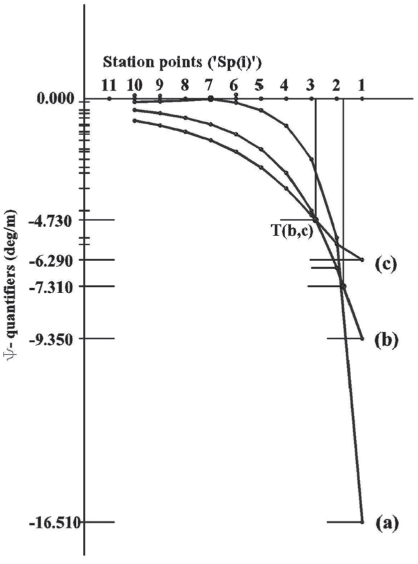


Figure 10. Dynamics of an angular size illusion, noticeable during the movement throughout architectural and urban patterns represented by the model EM-1 (trend-line (a)) and its two sub-models: EM-1/a (trend-line (b)), and EM-1/b (trend-line (c)).

These trend-lines represent the illusion dynamics behavior (related to all defined examples) through the flow-characteristics of the corresponding Ψ-quantifiers (related to each pair of consecutive station-points) and obtained under the influence of the established determinants (**6**).

Common Remarks

By analyzing the trend-lines on **Figure 9** and **Figure 10**, it can be observed that Ψ-quantifier's trend-lines are continual and smooth, showing identical distribution characteristics through a continual and uniform illusion dynamics-flow. This is expected because the corresponding Δ-quantifier's trend lines were also alike. Such a tendency is present in all examples over the duration of each exhibited illusion.

Consistent with the meaning of the Ψ-quantifier, the level of its trend-line inclination describes the changing rate level that refers to the corresponding pair of the consecutive Δ-quantifier's values (over the corresponding sequence of the illusion duration) and thus, the extent of the dynamics of the marker-to-focus dimensional seeming-change impression (the steeper the trend-line, the larger the illusion dynamics). In case of the zero-value of the Ψ-quantifier (or almost zero-value), there is no illusion dynamics at all (or it is insignificantly small) during the perception from successive station-points that correspond to such an insignificant Ψ-quantifier's value. Also, because all analyzed trend-lines are located below the abscissa, their corresponding Ψ-quantifiers have negative values (the meaning is explained in sub-section named: Starting Considerations).

By comparing the trend-lines showing the illusion dynamics (**Figure 9**), it is obvious that their dynamics-flows are almost identical, but with some differential/specific characteristics.

So, in all three examples, the small starting values of the illusion dynamics (present at a movement-path interval defined between the starting positions (11→10) and the mid-positions (7→6)) can be treated as insignificant. It means that each analyzed illusion, persistent along that first half of the corresponding movement-path length, can be commonly characterized by the presence of insignificant levels of the illusion dynamics. But, from positions 6→5 to positions 2→1, the illusion dynamics gradually increases, to finally gain a dramatic character (described by the presence of very abrupt ending parts of all trend-lines). Such a final tendency indicates an evident rate-increase of the marker-to-focus dimensional seeming-change, so that the observer gets the impression that the corresponding foci heights are permanently sinking more and more dynamically with respect to those of their markers (by reaching both).

By comparing the trend-lines shown on **Figure 10**, it is evident that there are some important differences.

Specific Remarks

A differential analysis of the trend-lines on **Figure 9** shows that there are two behavioral characteristics of the illusion dynamics (related to the ending movement intervals) that differ in the case of the analyzed examples.

Firstly, regarding the trend-line inclination, it is evident that the steepest dynamics trend-lines (and mutually identically inclined) are those related to the models EM-1 (trend-line (a)) and EM-3 (trend-line (c)) – showing the most dramatic (and almost the same) increasing tendency. Contrarily, in

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6. For a better layout of the illusion dynamics trend-lines, the Ψ-quantifier's values are enlarged twice.

the model EM-2 (trend-line (b)), its trend-line is less abrupt, pointing to a less dramatic increase of the corresponding illusion dynamics.

Secondly, according to the concrete Ψ-quantifier's values that relate to the ending observer's positions (2→1), the lowest is in the model EM-2: 9.878 deg/m, while the highest (and almost identical) are in the model EM-1: 16.510 deg/m and EM-3: 16.697 deg/m.

A differential analysis of the trend-lines on **Figure 10** shows that the main characteristics of the illusion dynamics behavior relating to the model EM-1 have already been elaborated (see: trend-line (b) / **Figure 9** = **Figure 10**: trend-line (a)).

Regarding the sub-models EM-1/a (trend-line (b)) and EM-1/b (trend-line **(**c)), the illusions that appear as the observer moves from the starting positions 11→10 to the positions 4→3 (that approximately refer to mark signed with letter T(b, c) as an intersection point of those trend-lines) are characterized by similar dynamics-flows. Namely, the parts of these trend-lines that relate to the analyzed segments of the corresponding paths are similarly inclined with less abrupt slopes than in the model EM-1 (expressing a higher illusion dynamics than that of the model EM-1). According to the common differences between these sub-models (regarding the same path-interval), it is obvious that in the sub-model EM1/a, its trend-line (b) is slightly steeper than the other one (c), expressing a pretty higher illusion dynamics.

According to the Ψ-quantifier's values present at the very beginning of the movement, it can be noted that these values are too small in both sub-models (so that they can be identically treated as insignificant), while in EM-1 (trend-line (a)), the corresponding starting Ψ-quantifier value is almost zero.

As the observer continually moves along each of the three analyzed paths, from positions 4→3 to the corresponding markers/foci, the mutual dynamics-flow differences in all those cases become obvious. The most dramatic illusion dynamics increasing tendency is observed in the model EM-1 (trend-line (a)), while a smaller appears in both sub-models. Thus, it is important to indicate that the illusion dynamics-flow related to the sub-model EM-1/b (trend-line (c)) (contrary to the sub-model EM-1/a (trend-line (b)), shows a characteristic inversion in its behavior, expressed by an evident and permanent illusion dynamics decrease.

Reaching the corresponding markers/foci, the highest level of ending illusion dynamics is achieved in the model EM-1: 16.510 deg/m, then in its sub-model EM-1/a: 9.350 deg/m and, finally, in the sub-model EM-1/b: 6.290 deg/m.

General Conclusions

Irrespective of whether the movement-path is horizontal, inclined or declined, for the defined experimental pre-sets, there are no important differences in the dynamics behavior of the exhibited illusion. In all foregoing cases, the starting level of the illusion dynamics is insignificant in the first half of each movement-path length, but it starts to increase during their second halves. As the observer is about to reach the corresponding markers/foci, the illusion dynamics rapidly keeps growing in all three cases, so that its most dramatic ending character (and almost mutually identical) shares cases of a horizontal and an inclined path, while the ending illusion dynamics is much smaller when the path is declined.

On the other side, notwithstanding the height of the markers with respect to those of the foci, as the observer starts to move towards the corresponding foci, for all analyzed height-interrelations, the starting illusion dynamics is insignificantly small (it is the largest when the marker is higher than the focus, then when these heights are equal and, finally, when the marker is lower than the focus). In all three cases, such dynamic tendency remains during the perception from the positions that belong to the starting paths segments whose lengths approximately reaches 0.7 of the entire paths lengths. Also, in all these cases, as the observer approaches the corresponding markers/foci (perceiving them at mutually similar distances whose lengths approximately reaches 0.2 of the entire paths lengths), the illusion dynamics keeps increasing permanently but, very soon, the nature of such a common trend interchanges. Namely, in the case when the marker is higher than the focus (contrary to the case when these heights are mutually equal), the corresponding illusion dynamics shows an evident and permanent decreasing tendency. The ending illusion dynamics becomes the highest when the marker is lower than the focus; the ending illusion dynamics is lower when the heights of the marker and focus are equal while it is the smallest when the marker is higher than the focus.

FINAL REMARKS

Based on previously investigated behavioral characteristics of an angular size-illusion (existent during the observer's movement throughout architectural and urban patterns of analyzed characteristics), it becomes possible now to detect in reality (or set in advance early in the design-stage), the exact moment, that is the location/station-point of the illusion triggering/appearance and its noticeability (including duration, dynamics and the value of the present -or desired- finally achieved overall impression of the perceived objects as the foci of interest). Consequently, according to the investigated illusion determinants (inclination of the existent or planned linear observer's routes as well as spatial and metric interrelations between urban masses- existent or planned to be along those routes, including architectural objects that are located or will be positioned at the end of the routes), route-ending objects are (or could be) perceived as volumetrically and, thus, semantically dominant or, contrary, accidentally degraded.

Given the afore, this research can apply on adequate design of architectural and urban matrices (new pedestrian linear routes surrounded by properly modelled new urban masses), when one wants that existent ending-route objects not only physically dominate their very close newly-designed neighborhood but be perceived as increasingly monumental as the observer reaches them. Contrarily, the same effects of the analyzed type of illusion are achievable when it is triggered in existent architectural and urban matrices, following adequate designing (volumetric modelling) of new ending-route objects that ought to be perceived as monumental. For example, when existent ending-route objects, also located in the old urban matrices, need to become the objects of the illusion, it is possible to perform appropriate volumetric/dimensional interventions on those objects and/or on their physical surrounding (with respect to results and conclusions of this study), so as to ensure a perception that guarantees activation and desired duration of the illusion (provided urban regulations allow such illusion-dependent reconstructions).

Additionally, it is important to say whether this investigated illusion appears in already built structures (in reality) or ought to be planned in advance (while designing or reconstructing architectural and urban matrices in a subject-related sense), illusion simulation can easily be performed virtually by using modern 3D visualization and digitization tools (including virtual reality (VR)). These tools allow also real-time interactive control of all investigated behavioral characteristics of the illusion: either inherited (in reality) or pre-defined ones (when the illusion is programmed). Namely, digitization software (that transforms existent 3D spaces into digital 3D scenes) and visualization software (that converts non-existent/newly designed spaces, represented by 2D drawings, into digital 3D scenes), allow us to manipulate with contained digital objects (to move and/or remodel them, if necessary) and, thus, to control the illusion behavior: 1. analytically: by computing established values of Ψ-quantifiers (based on graphic measurements of relevant visual angles represented by Δ-quantifiers- extracted directly from the generated virtual 3D spaces), and 2. visually - by tracing visual impression changes while walking virtually throughout those digital spaces.

OUTLOOK

Since the architectural and urban scenes are characterized by large amounts of information (present in different depth planes), during the observer’s continual movement (under the influence of visual, selective and controlling attention mechanisms), the informative quality of such space inevitably leads to dynamic changes to his subject of interest: from close, to newly focused targets located faraway (Milosevic, 2002; Lee et al., 2015). The consequence of these mechanisms is a reorientation of the perception direction (with or without head or eye movement) and, thus, a permanent reorganization of the visual field (causing the objects of the focus and/or the marker as well as their perceived volumes/contour-lines to change). So, a future work will investigate the behavioral characteristics of an angular size-illusion –_not simulated but exhibited in real environments, full of various positive and negative contextual factors/signals.

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Anahtar Sözcükler: Mimarlık; açısal boyut yanılsaması; yanılsamanın fark edilebilirliği; yanılsama süresi; yanılsama dinamikleri.

MİMARİ VE KENTSEL CİSİMLERİN GÖRÜŞ AÇISINA GÖRE BOYUT YANILSAMASI DAVRANIŞI ÜZERİNDEKİ ETKİLERİ

Bu çalışma, var olan bir araştırmanın devamı niteliğindedir. Söz konusu bu araştırma, görüş açısına göre oluşan boyut yanılsamasının, gözlemcinin nesneleri algılaması üzerinde çelişkili etkiler yaptığını doğrulamaktadır. Şöyle ki, gözlemcini yaklaşmasıyla birlikte gözlemcinin bakışının odağındaki mimari ve kentsel cisimler belirgin bir ölçek-boyut küçülmesine maruz kalmaktadırlar. Makale, çeşitli mimari ve kentsel dokuların (nesnelerin), hareket sırasında fark edilen açısal boyut yanılsaması üzerindeki etkilerini araştırmaktadır. Sürdürülebilir sonuçlar elde edebilmek için gerçek çalışma alanları seçilmiş ve bu alanlar ve basitleştirilmiştir. Basitleştirme ölçütleri söz konusu yanılsamanın tetiklenmesi için gerekli önkoşulların sağlanmasıyla tanımlanmıştır. Ayrıca, hem yanılsama niteleyicileri hem de yanılsama niceleyicileri olarak iki grup parametre formüle edilmiştir (tanımlayıcılar ve belirtkenler). İllüzyon niceleyicinin davranış üzerindeki analizi sonucunda, belirlenmiş olan değerlendirme ölçütleri, tanımlayıcıların davranışı üzerine belirleyicinin etkisi hakkında metodolojik inceleme yapma fırsatı yaratmıştır. Çıktı-temelli sonuçlar güncel mimari ve kentsel uygulamalara göre genelleştirilerek gerçek hayatta yanılsamanın tahmini ve davranışının kontrol edilmesi mümkün kılınmıştır.

THE IMPACT OF ARCHITECTURAL AND URBAN PATTERNS ON THE BEHAVIOUR OF AN EXHIBITED ANGULAR SIZE-ILLUSION

This paper continues a research in which it has been confirmed that the angular size-illusion underpins a contradictory effect related to a seeming size-decrease of focused architectural and urban objects as the observer approaches them. It explores the impact of various architectural and urban patterns on the behavior of an angular size-illusion noticeable during movement. To obtain sustainable conclusions, real locations are selected and simplified. Simplification criteria are defined respecting the preconditions necessary to trigger such an illusion. Also, two groups of parameters are formulated, both as illusion quantifiers and illusion qualifiers (such as descriptors and determinants). By analyzing the illusion quantifier's conduct, the established valorization criteria allowed the methodological investigation of influences of illusion determinants on the descriptor's behavior. The outputs-based conclusions are generalized in a form applicable to contemporary architectural and urban practice, making it possible to estimate and control the behavior of the illusion in reality.

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