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VISUAL SHAPING OF BUYERS' PERCEPTION IN ARCHITECTURAL OFFER MANAGEMENT - ANALYSIS USING ADVANCED PSYCHOPHYSIOLOGICAL METHODS

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ABSTRACT

Purpose: *This publication presents the results of a study on the impact of unconventional (surreal) architectural visualisation settings on the perception of single-family house design. Particular emphasis was placed on analysing the audience's emotional and cognitive reactions.*

Need for the study: *Research to date does not provide in-depth analyses of the impact of non-standard landscapes, such as surreal mountains or seascapes, on the perception and evaluation of architectural designs. Furthermore, there is a lack of research in this area using psychophysiological methods (EEG, GSR, eye tracking), a significant research gap.*

Methodology: *The study was conducted in a laboratory using advanced methods such as EEG, GSR, eye tracking and facial expression analysis. Participants viewed different variants of house visualisations (daytime and surreal versions). Based on physiological measurement data, metrics were determined to analyse and interpret emotional and cognitive responses.*

Findings: *Analyses have shown that an appropriately chosen environment for architectural visualisations can significantly influence the perception of single-family house designs. It can intensify emotional and cognitive reactions in both positive and negative directions. These effects appeared to depend on the specific design and the type of setting (mountain, sea).*

Practical Implications: *The study's results may be of great practical importance for architects and graphic designers involved in creating architectural visualisations and for people and companies involved in selling single-family house designs. Appropriately designed, unconventional scenery can increase an offer's attractiveness, evoke positive emotions, and improve a design's memorability.*

Keywords: Architectural visualisations; offer management; psychophysiological studies; EEG (Electroencephalography) analyses; GSR (Galvanic Skin Response) analyses; eye tracking analyses; neuromarketing in architecture

Jel codes: M31; D87; C91

1. INTRODUCTION

A photo of the house exterior is an integral part of every property sales offer. This photo is usually the starting point for house buyers to analyse the offer and it is also the one they focus on for the relatively longest time (Seiler et al., 2012). This shows that the attractiveness of the exterior of a house, commonly referred to as curb appeal, is an important factor influencing the decision to buy a house. This is confirmed both by research results (Bessinger & Jacobs, 2016; Glaeser et al., 2018; Johnson et al., 2020) showing the impact of curb appeal on the selling price of a property, as well as countless websites, blogs and videos advising on how to improve curb appeal. Similarly, the issue of curb appeal arises when we replace house sales offers with house plans offered to those who intend to build their future home. Here, too, we can expect the visualisation of the offered house plan to play an important role. Moreover, while the improvement of curb appeal is limited and costly for an existing house, the possibilities are much wider here. Current house plan visualisations are by no means limited to presenting the building's shape, but place it in a photorealistic scenery of a perfectly designed front yard with an elaborate play of light and shadow. Thus, they can arouse buyers' aesthetic experiences and emotions and, as we will discuss more broadly in the next section, translate into their perception, attention, memory and decision-making. Is this really the case? Can changes in the environment of the building significantly alter the assessment of the house itself, even when the buyer realises that the created setting is fictitious?

As studies on similar topics (Assem et al., 2023; Khaleghimoghaddam et al., 2022; Vecchiato et al., 2015; Weinberger et al., 2021) show, a number of interesting findings on this problem can be provided by research using psychophysiological methods. In the case of architectural visualisations, experiments can be even more reliable because we can place the same building in any chosen setting and thus focus on selected, isolated issues. The aim of the presented research was to analyse changes in the perception of house plans by potential buyers influenced by the transfer of the house from the classic environment of a suburban residence to landscapes of a mountain meadow and a seaside shore, which are unusual for this type of project. In particular, the study examined whether the use of an unconventional landscape (for simplicity, referred to below as 'surreal') increases the level of emotional arousal, influences the direction of motivational responses (approach-avoidance), and shapes the way the viewer focuses their visual attention. Psychophysiological methods such as electroencephalography (EEG), galvanic skin response (GSR), eye tracking and facial expression analysis were used to conduct the research. The use of such techniques is an increasingly common practice in research on human interaction with visual stimuli, as confirmed by previous work on the integration of cognitive neuroscience methods in user experience analysis (Borawska & Mateja, 2024; Niemcewicz, 2023; Zhu & Lv, 2023).

The publication is structured in five parts. Section 2 discusses research on architectural visualisations and their impact on consumers. Section 3 (Materials and Methods) contains a description of the participants, the experimental procedure, the tools, analyses and measurement metrics used. Section 4 (Results) presents the main research results together with statistical analyses. Section 5 (Discussion) discusses and interprets the results. The last part of the paper (Conclusion) contains the final conclusions and practical implications of the obtained results.

2. ARCHITECTURAL VISUALISATIONS AS A FACTOR INFLUENCING HOUSE PLAN BUYERS

The impact of architectural visualisations on buyers is not only due to the obvious role of image in advertising, but also to the human reaction to the built environment. Research conducted over the past decade using psychophysiological methods (a systematic review of which can be found in (Assem et al., 2023; Bower et al., 2019; Lee et al., 2022) clearly shows that the visual properties of built environments cause a range of neural and physiological activities, thus affecting the emotional states of the recipient. In the case of interior spaces, it has been shown that aesthetic judgements are influenced by, among other things: ceiling height, perceived enclosure (open vs. closed), changes in contours (curvilinear vs. rectilinear), interior furnishings (unfurnished vs. furnished spaces), or the photorealism of the spaces presented (Grima Murcia et al., 2019; Vartanian et al., 2013, 2015; Vecchiato et al., 2015). With regard to external architectural spaces, for example, the reactions to familiar and unfamiliar locations or the reactions of experts and nonexperts were compared (Epstein et al., 2007; Kirk et al., 2009). The results of a study by Khaleghimoghaddam, Bala, Ozmen and Ozturk (Khaleghimoghaddam et al., 2022) on functional magnetic resonance imaging suggest that "the external appearance of an architectural setting can influence the emotional, perceptual, cognitive, beauty judgment, and decision-making (behavioral) process for users to a high degree". Unfortunately, there has been significantly less research on external architectural spaces than on interiors. Moreover, this research has focused on a narrower range of issues, concentrating mainly on aesthetic experiences and emotions, while ignoring their impact on purchasing decisions. In turn, studies analysing the impact of curb appeal on purchasing decisions did not use psychophysiological methods but focused on models for predicting property prices. For example, Bessinger and Jacobs (2016) found that combining objective attributes with curb appeal data allows for more accurate estimates of home prices. However, neither this study nor the studies by Glaeser, Kincaid and Naik (2018) or Johnson, Tidwell and Villupuram (2020) can identify significant environmental characteristics, as in each case the assessment of building photographs was performed using machine learning methods.

Nevertheless, these studies suggest that the same house plan presented in two different settings can evoke different aesthetic experiences and emotions. Our intuition tells us the same thing. Visualisation designers are also aware of this, and consider the elements of the environment and the realism of lighting and objects to be the main factors determining the positive perception of visualisation (Bogdanowicz & Cypryjański, 2017). However, a better understanding of this issue requires focusing on two questions. The first is how to change the environment in the visualisation, which elements of the environment are important and how to present them to evoke positive aesthetic experiences and emotions in the viewers. The second is whether the aesthetic experiences and emotions evoked by these changes have an impact on purchasing decisions.

It is also important to take into account current research in the social psychology and affective sciences when addressing these two questions. With regard to the first question about changes in the environment and their impact on aesthetic experience and emotions, it is primarily about the role of conscious awareness. Bargh (Bargh, 2002, 2022) discusses a series of field experiments that illustrate the wide range of consumer behaviour that is strongly influenced by factors outside conscious awareness. Chartrand (Chartrand, 2005; Chartrand & Fitzsimons, 2011) distinguishes between three areas of unawareness: "consumers are often unaware they have been exposed to an environmental cue that triggers a given consumption behavior, or are unaware of a mental process that is occurring outside conscious awareness, or are even unaware of the consumption-related outcome of such a nonconscious process". Chartrand and Fitzsimons (Chartrand & Fitzsimons, 2011) also emphasise that virtually all consumer psychological processes are on a continuum from highly conscious to entirely unconscious and therefore postulate that the role of unconsciousness should be taken into account in the study of motivation, emotions and consumer decision-making. Also from the work of Bargh (Bargh, 2022) comes a practical conclusion regarding the design of field experiments: since consumers may not be aware of the impact of certain triggers, processes or their effects, they are also unable to self-report them accurately.

With regard to the second question, it should be pointed out that the human mind has long been considered to be a place where two opposing forces clash: rational and deliberate reason, and impulsive and irrational emotions. As a result, emotions have been treated as factors that can interfere with cognitive functions such as perception, attention, memory, and decision-making. However, as the authors of the review (Brosch et al., 2013) of research in the field of affective sciences conclude, the dualism of reason and emotion is not reflected in the architecture of the brain and the functioning of the mind. Emotions and cognition are closely related, and complex human behaviour emerges from the dynamic interactions between multiple processes and brain networks. Emotions determine how we perceive our environment, how we remember it and what decisions we make.

3. MATERIALS AND METHODS

3.1. Participants

Thirty-two participants (15 women and 17 men) aged between 17 and 73 years (M = 32.34; SD = 15.90) participated in the study. The sample comprised people of varying occupational status and educational levels. Participants included students, working people and one pensioner. Participants were randomly divided into two groups (A1 and A2). Each group completed the same research task, with differences in the variants and order of presentation of the visualisations of the single-family house designs.

The main eligibility criteria for the study were having good or corrected vision and no known neurological disorders that could affect the results of the psychophysiological measurements. One left-handed person was in the study group (3% of the sample), which was considered in the analysis of cerebral asymmetry in the EEG measurements. The structure of the study, the participant eligibility criteria adopted and the results were based on previous analyses and documentation of the research work (Bogdanowicz, 2023).

Before the experiment, each participant was informed about the experiment (without disclosing detailed assumptions) and the measurement tools used. All subjects signed an informed consent to participate in the study and to process their data by RODO regulations. They were also told that they could opt-out at any stage without giving a reason. The study was conducted by the principles of the Declaration of Helsinki (World Medical Association, 2013). The Bioethics Committee of the Regional Medical Chamber approved the research project in Szczecin (Resolution No. 02/KB/VII/2020 of 18 June 2020).

All participants completed the study; however, due to technical problems related to the quality of the EEG signal, the data of 2 subjects were partially excluded from the final analysis. The remaining data from the physiological measurements were used in the analyses.

3.2. Research Protocol and Stimuli

The study was conducted under controlled laboratory conditions, following an established experimental protocol. Each participant entered the study individually, in a neutral environment, which allowed for the minimisation of factors that could interfere with psychophysiological reactions. During the experiment, participants were presented with visual stimuli on a computer monitor, visualisations of single-family house designs. Two different architectural designs were considered, presented from two perspectives (front and back of the building):

- PA - single-storey building with a total area of 135 m2 with a built-in garage and terrace;
- PB - ground floor building with a total area of 126 m2 with large glazed areas and a terrace.

Each house design was presented in two visual options:

- standard version (STD) - realistic visualisation of the building in a typical daytime setting,
- surreal version (SUR) - house design placed in a modified, non-standard setting.

In the surrealist version, two variants were considered, which differed in the type of environment in which the building was located:

- surreal mountain landscape (SUR_M) - a building set in a high mountain setting, characterised by lots of greenery and open space,
- surreal seascape (SUR_S) - a coastal building with open space and the sea in the background.

The following stimulus symbolism was adopted to facilitate the analysis:

- **PA_STD - design A, standard version (fig. 1),**
- **PA_SUR_M - design A, a surrealistic version of mountain scenery (fig. 2),**
- **PB_STD - design B, standard version (fig. 3),**
- **PB_SUR_S - design B, the surrealistic version of marine scenery (fig. 4).**

Figure 1. Project visualisation of house A in standard version (PA_STD)
Source: compiled based on: projekty.muratordom.pl.

Figure 2. Visualisation of house project A in surrealistic version - mountain scenery (PA_ SUR_M)
Source: compiled based on: projekty.muratordom.pl.

Figure 3. Project visualisation of house B in standard version (PB_STD)
Source: compiled based on: projekty.muratordom.pl.

Figure 4. Visualisation of house project B in surrealistic version - marine scenery (PB_ SUR_S)
Source: compiled based on: projekty.muratordom.pl.

Depending on the group to which respondents were assigned (A1 or A2), they were presented with a different variant of the visualisation of the houses - either a standard or surreal version.

The experiment consisted of two main stages: participant preparation and stimulus presentation.

1st Preparation of the participant - briefing about the experiment, obtaining consent to participate in the study and to process data, seating the participant at the test stand, fixing the measuring apparatus and setting up and calibrating the sensors (EEG, GSR, eye tracker).

2nd Visual stimulus presentation - start the study and display successive visualisations of the houses in different variations.

3.3. Research Apparatus

Advanced research equipment was used to record participants' psychophysiological responses and measure physiological parameters. The measurement system included an electroencephalograph (EEG), skin-galvanic response (GSR) sensors, an eye tracker, and a camera for recording facial expressions.

The study of brain electrical activity was carried out using the ENOBIO 20 5G system (Neuroelectrics), equipped with 20 electrodes arranged according to the international 10-20 system (Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, T7, C3, Cz, C4, T8, P7, P3, Pz, P4, P8, O1, O2). The sampling rate was 500 Hz, and data were transmitted wirelessly to a computer.

Electrodermal activity was recorded using the Shimmer3 GSR+ Unit, which allows measurement of both tonic and phasic GSR activity. Skin conductance sensors were placed on two fingers of the participant's non-dominant hand. The signal was recorded at 16 Hz, and data transmission to the computer was via Bluetooth technology.

Participants' eye movements were monitored using a stationary Tobii Pro X3-120 eye tracker mounted under the monitor screen. The device recorded data at 120 Hz, which allowed precise detection of fixations, saccades, and other visual perception parameters. The eye tracker's calibration was 9-point, and the participants' distance from the monitor was between 60 and 63 cm. Data were wired to the computer via USB 3.0.

Facial expressions were recorded using a Logitech BRIO Webcam 4K, centrally placed above the monitor screen. The camera could record images in 4K Ultra HD (30 fps) or 1080p (30/60 fps). Connection to the computer was via USB 3.0.

All signals were synchronised and recorded using the iMotions platform (*iMotions*, 2024), enabling the integration of EEG, GSR, eye tracking and facial expression analysis data. The system allowed simultaneous processing of multi-channel data and its export for further analysis, including statistical analysis.

3.4. Analysis of Measurement Data

Data analysis involved two main stages: signal pre-processing and the determination of key indicators (metrics). In the preprocessing stage, signal filtering, cleaning and normalisation procedures were applied to eliminate artefacts and improve data quality.

The preprocessing of the EEG signals involved several steps. In the first step, a visual analysis of the signals from all channels was performed. Next, a fifth-order Butterworth filter (range 2 – 45 Hz) was applied to eliminate slow trend and high-frequency interference, e.g., muscular origin. An artefact threshold of ±90 μV was adopted to reject signal fragments with an outlier amplitude. The Welch method was used to exclude interference, in which the EEG data were divided into 1-second time windows with 50% overlap. A Fast Fourier Transform (FFT) was then performed, generating one power spectrum per 0.5 seconds. Hamming time windows were used in the Welch method. The corresponding power spectrum was discarded for signal amplitudes exceeding a threshold value (Heinzel & Rüdiger, 2002; Semmlow, 2012).

Pre-processing of the GSR signal included verifying the quality of the recorded signal and eliminating artefacts. Signal quality was determined by the SNR parameter (signal power-to-noise ratio) expressed in decibels. Signal fragments with SNR values below 10 dB were considered of low quality and excluded from further analysis (Schumm et al., 2008).

The I-VT algorithm was used to analyse the recorded eye-tracking data and to classify fixations and saccades (Olsen, 2012).

After processing the raw signals, key psychophysiological metrics were calculated based on EEG measurements, GSR, eye tracking and facial expression analysis. These enabled the assessment of participants' responses at the physiological level.

The cleaned EEG data were analyzed using power spectral density (PSD) calculations. The PSD values determined the Frontal Alpha Asymmetry (FAA) and the Memorisation Index (MI).

- The FAA was designated according to the formula:

$$FAA = ln(P_{alfa\,F4}) - ln(P_{alfa\,F3}) \tag{1}$$

where: $P_{alfa\,F4}$ i $P_{alfa\,F3}$ denote the alpha band power at the respective electrodes.

It has been shown that there is a relationship between asymmetry of cortical activity and motivational-emotional processing. The left frontal part of the brain is more involved in processing stimuli and behaviours associated with a positive attitude (approach motivation), while the right frontal part of the brain is more involved in processing negative stimuli (avoidance motivation) (Allen et al., 2004; Davidson, 1992; Davidson et al., 1990; Pizzagalli et al., 2005).

- MI was derived from the formula:

$$MI = ln(P_{theta\,Fp1,F3,F7}) \tag{2}$$

where: $P_{theta\,Fp1,F3,F7}$ denotes the power of the theta band at the corresponding electrodes.

The memorisation index was determined according to the Hemispheric Encoding/Retrieval Asymmetry (HERA) model proposed by Tulving and colleagues. The theoretical basis of this model assumes the presence of hemispheric asymmetry in the encoding and retrieval of episodic information.

According to this model, the left cerebral hemisphere prefrontal cortex is more involved in encoding information, and the right cerebral hemisphere prefrontal cortex is more involved in extracting it. (Tulving et al., 1994). The dominant current theories, confirmed by EEG and MEG studies, assume that episodic memory is positively related to theta oscillations (4 – 8 Hz) (Hasselmo & Stern, 2014; Kraus et al., 2013).

Two metrics from the GSR signal were used to analyse the emotional response. The first is the number of GSR peaks, and the second is the amplitude of the GSR peaks (μS). To obtain these metrics, the phase part of the GSR signal was extracted using a median filter within a fixed length time window (8000 ms). The number of GSR peaks determines the frequency of emotional arousal per 1 minute of stimulus presentation. The amplitude of the GSR peaks makes it possible to assess the strength (intensity) of a single response (Benedek & Kaernbach, 2010; iMotions, 2017). The GSR peak was counted if the amplitude exceeded 0.005 μS and if the time between onset and offset was more significant than 500 ms.

Facial expression analysis (FEA) was carried out using the AFFDEX module to identify basic emotions, additional emotional states, and other quantities (Bishay et al., 2022). It was assumed that classification of expression measures would be made for moderately strong facial responses. Threshold values for emotion identification, action units and valence were 50%. When aggregating the data, the time window over which the data were analysed for the participant groups was set to 500 ms.

Analysis of the eye tracking data included the creation of gaze paths for individual study participants, generating heat maps for the study groups considered, and determining metrics for defined areas of interest (AOI). Several key AOI metrics were analysed, such as RC (%) - the percentage of respondents who noticed a given area of interest; FC – the average number of fixations; FFD (ms) – the average duration of the first fixation; DAF (ms) – the average duration of all fixations; TTFF (ms) – the time to first fixation; DT (%) – the percentage time looking at a given AOI; and R – the number of revisits.

Different methods were used for statistical analyses of the data extracted from the physiological measurement, depending on the nature of the data. These included descriptive statistics including Student's t-test (for independent samples).

4. RESULTS

This section presents the results of a psychophysiological study in which the previously discussed methods of EEG analysis, GSR, eye tracking and facial expression enabled the assessment of participants' responses to visual stimuli. Two house designs presented in different visual variations (PA_STD, PA_SUR_M, PB_STD, PB_SUR_S) were analysed to determine the effect of modifications on architectural perception. The results were complemented by declarative surveys, which provided assessments of the visualisation, costing, and functionality of the designs.

The analysis of the results from the physiological measurement began with an examination of whether and to what extent the presented stimuli (variants of the visualisations of the house designs) elicited spontaneous responses linked to emotional arousal. For this purpose, the skin-galvanic response measurement was used, which allows the recording of unconscious bodily reactions reflecting the level of in the reception of the stimulus. Table 1 shows the mean values of the number and amplitude (μS) of GSR peaks per 1 minute for the different visualisation variants. In contrast, Table 2 compares the standard and surreal variants, considering the results of statistical tests and differences in mean values.

Table 1. Average GSR values for individual visualisation options.

Variant	Number of GSR peaks (mean ± SD)	Number of GSR peaks (min-max)	GSR amplitude (mean ± SD)	Amplituda GSR (min-max)
PA_STD	3.55 ± 3.09	1.12 – 6.87	0.052 ± 0.031	0.007 – 0.114
PA_SUR_M	6.43 ± 3.42	2.34 – 9.14	0.079 ± 0.068	0.019 – 0.254
PB_STD	5.08 ± 1.84	3.21 – 7.42	0.063 ± 0.043	0.020 – 0.169
PB_SUR_S	1.84 ± 2.66	0.00 – 4.52	0.098 ± 0.033	0.026 – 0.141

Source: own elaboration.

Table 2. Comparison of GSR values for visualisation options *(* p < 0.05)*.

Variants	t	df	p-value	The difference in the average number of GSR peaks	Difference in mean GSR amplitudes
PA_STD vs PA_SUR_M	-2.03	19	0.057	+2.88	+0.027
PB_STD vs PB_SUR_S	2.61	14	0.020*	-3.24	+0.035

Source: own elaboration.

The GSR analysis showed significant differences in emotional arousal depending on the variant of visualisation of the house designs. In the case of the PA design, the surrealist version with mountain landscape (PA_SUR_M) had a higher number of GSR peaks (M=6.43, SD=3.42) compared to the standard version PA_STD (M=3.55, SD=3.09). Analysis by Student's t-test showed that this difference was close to statistical significance (t(19)=-2.03, p=0.057), which may suggest greater emotional involvement of participants in response to this variant of the visualisation. In addition, the amplitude of GSR peaks was also higher in the surreal version (M=0.079 μS, SD=0.068) compared to the standard version (M=0.052 μS, SD=0.031), confirming the higher intensity of the emotional response in the case of an unusual mountain environment.

The results obtained for the PB project indicate the opposite effect. The surrealistic variant with seascape (PB_SUR_S) resulted in a significantly lower number of GSR peaks (M=1.84, SD=2.66) compared to the standard version PB_STD (M=5.08, SD=1.84). The Student's t-test showed that this difference was statistically significant (t(14)=2.61, p=0.020), suggesting that the atypical setting may have influenced participants' emotional arousal reduction. Other correlations were observed for the amplitude of GSR peaks, which was higher in the surreal variant (M=0.098 μS, SD=0.033) compared to the standard PB_STD (M=0.063 μS, SD=0.043).

In the next step, the EEG results were analysed, focusing on the frontal asymmetry alpha (FAA) and the memory index (MI). These analyses assessed whether using different visualisation variants affects motivational perceptual processes and the efficiency of encoding episodic information. Table 3 contains the averaged FAA and MI values for the different visualisation variants, while Table 4 contains the comparison results between standard and surreal variants.

Table 3. Average FAA and MI values of the visualisation options.

Variant	FAA (M ± SD)	MI (M ± SD)
PA_STD	-0.045 ± 0.019	5.13 ± 0.39
PA_SUR_M	0.096 ± 0.025	6.75 ± 0.45
PB_STD	0.036 ± 0.030	3.07 ± 0.26
PB_SUR_S	0.013 ± 0.027	4.18 ± 0.29

Source: own elaboration.

Table 4. Comparison of FAA and MI values for visualisation options *(* p < 0.05)*.

Variants	Indicator	t	df	p-value
PA_STD vs PA_SUR_M	FAA	–1.81	30	0.081
PA_STD vs PA_SUR_M	MI	–10.68	30	0.000*
PB_STD vs PB_SUR_S	FAA	0.25	30	0.804
PB_STD vs PB_SUR_S	MI	–11.52	30	0.000*

Source: own elaboration.

The FAA index, which is the logarithmic difference in alpha band power (8-12 Hz) determined for electrodes F3 and F4, indicates the approach or avoidance motivation in direction to the stimulus (visualisation). For design A, the standard version (PA_STD) obtained a mean FAA value of -0.045, while the surreal version in the mountain scene (PA_SUR_M) was 0.096. The Student's t-test showed that this difference did not reach significance ($t(30)=-1.81$, $p=0.081$). For design B, a comparison of the standard variant (PB_STD) where FAA=0.036 with the surreal version in a marine setting (PB_SUR_S) with FAA=0.013 revealed no significant differences ($t(30)=0.25$, $p=0.804$).

The MI, which reflects the efficiency of encoding episodic information and is related to activity in the theta band (4 – 8 Hz) at electrodes Fp1, F3 and F7, showed more pronounced changes. For design A, the standard variant (PA_STD) obtained a mean MI=5.13, while the surreal mountain version (PA_SUR_M) obtained a value of 6.75. Comparison of these values by Student's t-test showed a significant difference ($t(30) = -10.68$, $p<0.001$). For project B, the MI value was 3.07 for the standard variant (PB_STD) and 4.18 for the surreal marine version (PB_SUR_S), which also proved statistically significant ($t(30) = -11.52$, $p<0.001$).

These differences are shown graphically in Fig. 5, which illustrates the mean FAA values with standard deviations for the different visualisation variants, and in Fig. 6, which presents the mean MI values.

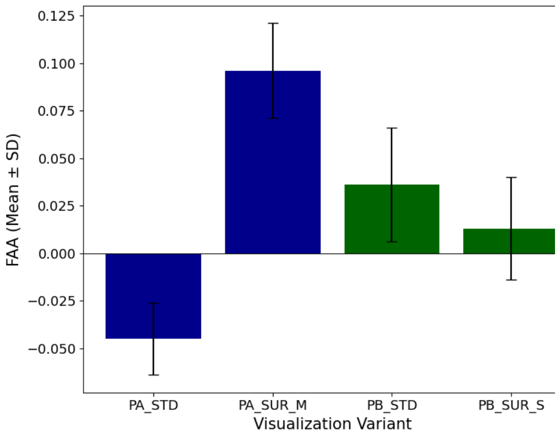

Figure 5. Mean FAA values.
Source: own elaboration.

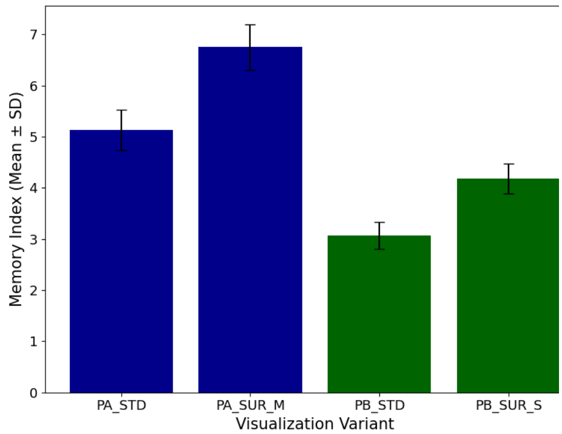

Figure 6. Mean MI values.
Source: own elaboration.

As can be seen, the mountain scenery increased the values of both indicators (FAA, MI) compared to the standard version, while the sea setting slightly decreased FAA and increased MI.

The study of facial expression aimed to determine the valence of emotions, and was a complement to the GSR measurements, which only record the intensity of reactions without determining their direction. The analysis results showed that, in the vast majority of cases, participants presented neutral facial expressions. This is probably related to the fact that the laboratory conditions induced a state of control over their facial expressions (Piwowarski & Wlekly, 2022). Therefore, further analysis of the impact of the visualisations on perception, based on the FEA results, was omitted, and the focus was on more objective measures such as GSR, EEG and eye tracking.

The eye tracking study aimed to determine how participants explore the visualisations of the house designs and which elements attract their attention depending on the visual context. In particular, the analysis of the heat maps made it possible to identify the areas with the highest concentration of fixation and the differences in visual exploration patterns between the standard and surreal versions. As part of the analyses, aggregated heatmaps were generated for two independent groups of participants, allowing a comparison of visual focus patterns under different visualisation conditions.

For the PA_STD variant, fixations were scattered throughout the object, mainly covering windows, doors, the facade and nearby environmental elements such as garden furniture and vehicles. There were no clear points of dominant visual focus, suggesting that participants' attention was evenly distributed across different aspects of the visualisation. For the PA_SUR_M (mountain scenery) variant, a significant change in visual exploration patterns was observed. Fixations were mainly focused on the windows and doors of the building, while the other elements of the environment (mountains) were scanned in a diffuse manner with no clear focus points. This is probably due to the fact that the mountain range in the background did not contain distinctive elements that could attract the subjects' attention. As a result, attention was focused on the central architectural aspects of the building, which may suggest a greater interest in its structure with limited influence from its surroundings.

The heat map for the PB_STD option showed a strong focus on key elements of the building, including windows, doors and the façade. There were also a number of fixations on surrounding elements, such as vegetation and garden decoration. This variant had a more balanced distribution of attention across the visualisation. For the PB_SUR_S (sea scenery) version, a similar concentration of fixations on windows and doors was observed. Still, an additional area of intense visual focus was the stretch of water visible in the left section of the image. The undulating surface of the sea attracted the subjects' attention, while in the right-hand section of the image, where the water was less visible, this effect disappeared. Compared to the mountain variant, where there was no characteristic focus of attention outside the building, the sea scene seems to generate additional points of interest in the background, which may affect the visual processing of the whole composition.

To determine which elements of the visualisation (e.g., the main body of the building, parts of the background, etc.) evoke which focus of attention of the participants and thus influence visual exploration, areas of interest were extracted, and metrics were counted for them. A graphical representation of the AOIs against the visualisation is available in Appendix A in Fig. A1 – Fig. A4.

Tables 5 and 6 contain the AOI values for house project A in the standard variant and mountain scenery. Tables 7 and 8 also contain AOI values but for project B in the standard variant and sea scenery.

Table 5. Values of AOI metrics for the PA_STD project option

AOI	RC (%)	FC	FFD (ms)	DAF (ms)	TTFF (ms)	DT (%)	R
hs_FR_PA_STD	100.00	7.64	169.34	217.45	476.39	14.34	2.14
hs_BA_PA_STD	100.00	7.13	224.99	214.13	1042.02	13.69	1.93
bh2_BA_PA_STD	13.33	1.00	249.94	249.94	4244.09	2.82	0.00
bh_FR_PA_STD	20.00	1.33	283.29	209.42	8274.25	1.90	0.33
bh_BA_PA_STD	20.00	1.33	175.04	165.10	7548.65	1.26	0.33
ph_FR_PA_STD	13.33	1.00	266.63	266.63	11548.82	2.32	0.00
tr_FR_PA_STD	40.00	3.50	166.48	184.28	2675.63	4.84	1.17
tr_BA_PA_STD	73.33	2.91	248.52	241.13	3656.19	4.60	0.64
bk_FR_PA_STD	13.33	2.00	195.69	233.26	3749.62	2.65	0.50
bk_BA_PA_STD	20.00	2.33	241.62	227.89	5999.29	3.28	1.33

Source: own elaboration.

In the standard variant (PA_STD), the main AOIs corresponding to the building shape, labelled as hs_FR_PA_STD (house shape in front view) and hs_BA_PA_STD (house block in rear view), achieved very high visibility (RC=100% in both cases). For hs_FR_PA_STD, the mean number of fixations was 7.64 and the time to first fixation (TTFF) was relatively short (476.39 ms), indicating that this area was quickly seen. The FFD (169.34 ms) and DAF (217.45 ms) values suggest that participants started to analyse the area fairly quickly and maintained fixations for a moderate amount of time. In contrast, for hs_BA_PA_STD, the FC (7.13) and TTFF (1042.02 ms) values are slightly higher, which may indicate a slightly later start of exploration of the second part of the building, although RC remains at 100%. Additional AOIs, such as areas of vegetation, pathways, terraces or backgrounds (in both views) show significantly lower RC values (ranging from 13.33% to 40.00-73.33%) and longer TTFF times (in the range 3749-11548 ms), indicating that the respondents noticed these areas less frequently and later and that their attention was mainly focused on the shape of the building.

Table 6. Values of AOI metrics for the PA_SUR_M project option

AOI	RC (%)	FC	FFD (ms)	DAF (ms)	TTFF (ms)	DT (%)	R
hs_FR_PA_SUR_M	100.00	9.36	247.33	213.08	997.54	18.29	2.86
hs_BA_PA_SUR_M	100.00	6.27	195.22	209.01	1779.27	11.89	1.60
ph_FR_PA_SUR_M	17.65	1.33	147.25	159.74	4233.36	1.25	0.33
bk_FR_PA_SUR_M	41.18	5.86	186.19	184.19	2869.90	8.68	1.43
bk_BA_PA_SUR_M	23.53	2.00	154.37	142.71	6786.85	2.05	0.25
an_FR_PA_SUR_M	17.65	1.33	577.44	649.62	14609.61	4.27	0.33
an_BA_PA_SUR_M	5.88	1.00	599.96	599.96	2821.52	2.22	0.00

Source: own elaboration.

In the variant with mountain scenery (PA_SUR_M), we observe significant changes in visual behaviour. For the AOI hs_FR_PA_SUR_M (shape of the house in frontal view), the RC is 100%, and the FC increases to 9.36, suggesting that the subjects performed more fixations on this area. At the same time, the TTFF for this AOI was 997.54 ms. This is significantly longer compared to the standard variant, indicating a delayed start of the principal component analysis, but once fixation started, it was maintained longer (DT = 18.29% vs. DT = 4.34%). For the AOI hs_BA_PA_SUR_M (shape of the house in rear view) the RC is 100%, but the FC is lower (6.27) compared to the front view, and the TTFF increases to 1779.27 ms, indicating that the rear view of the building was noticed later. For other AOIs in the surreal variant, such as ph_FR_PA_SUR_M (front path) and background areas on both sides (bk_FR_PA_SUR_M, bk_BA_PA_SUR_M), RC values range from 17.65% to 41.18%, indicating that a smaller proportion of subjects noticed these areas. However, their DT values (from 1.25% to 8.68%) indicate some focus in these areas. In addition, the animal-related AOIs (an_FR_PA_SUR_M and an_BA_PA_SUR_M) received low visibility (RC = 17.65% and 5.88%) and relatively long TTFF times (14609.61 ms and 2821.52 ms), indicating that these items were more difficult to identify quickly and may have required more perceptual effort.

Table 7. Values of AOI metrics for the PB_STD project option

AOI	RC (%)	FC	FFD (ms)	DAF (ms)	TTFF (ms)	DT (%)	R
hs_FR_PB_STD	100.00	9.88	181.82	205.75	1043.91	16.81	2.62
hs_BA_PB_STD	100.00	7.31	250.20	228.34	835.48	15.37	2.06
dc_FR_PB_STD	35.29	2.50	229.21	266.61	4146.91	3.91	1.00
ph_FR_PB_STD	11.76	1.00	149.98	149.98	16137.50	0.50	0.00
ph_BA_PB_STD	29.41	1.00	155.08	155.08	6406.04	1.45	0.00
tr_BA_PB_STD	47.06	2.38	192.77	201.09	3997.28	3.72	0.38
bk_FR_PB_STD	17.65	3.33	152.75	191.58	3358.64	3.08	1.67
bk_BA_PB_STD	23.53	2.25	174.99	237.98	3616.78	3.70	0.75

Source: own elaboration.

In the standard variant of design B (PB_STD), the body of the house was, of course, also viewed. For the area labelled hs_FR_PB_STD (the body of the house in front view), the mean number of fixations was 9.88 and the TTFF was relatively short (1043.91 ms), indicating that this area was noticed quickly. The FFD (181.82 ms) and DAF (205.75 ms) values suggest that participants started to analyse the area fairly quickly and maintained fixations for a moderate amount of time. For hs_BA_PB_STD (the body of the house in the rear view), the FC (7.31) and TTFF (83548 ms) values indicate a slightly later start to exploration of the second part of the building, although RC remains at 100%. Other AOIs, including ambient elements such as the deckchair, paths, terrace and backgrounds, show lower RC values (11.76% to 29.41%) and lower TTFF, FFD and DT metrics. This suggests that a smaller proportion of participants noticed these elements and generally later, and their focus of attention was less intense.

Table 8. Values of AOI metrics for the PB_SUR_S project option

AOI	RC (%)	FC	FFD (ms)	DAF (ms)	TTFF (ms)	DT (%)	R
hs_FR_PB_SUR_S	100.00	7.93	207.38	202.81	1642.40	12.94	1.71
hs_BA_PB_SUR_S	100.00	6.87	204.13	219.48	442.10	15.72	2.13
st_BA_PB_SUR_S	13.33	2.00	241.70	172.27	2950.45	2.26	0.50
se_FR_PB_SUR_S	60.00	3.44	235.75	239.36	1554.47	6.79	1.33
se_BA_PB_SUR_S	13.33	2.50	295.72	263.70	1748.38	8.16	1.00
ph_FR_PB_SUR_S	13.33	2.00	250.00	283.36	8747.98	2.70	0.50
bk_FR_PB_SUR_S	20.00	4.00	202.70	185.52	1844.59	5.47	1.33
bk_BA_PB_SUR_S	13.33	1.50	266.66	252.09	4756.74	3.62	0.00

Source: own elaboration.

In the surreal variant of this design (PB_SUR_S), the building block is viewed by all participants in the study. However, for the area hs_FR_PB_SUR_S (house in front), the average number of fixations dropped to 7.93, and the time to first fixation increased to 1642.40 ms, indicating a delayed start of exploration of the main area. For the rear view of the house (hs_BA_PB_SUR_S), the FC values were 6.87, and the TTFF was 442.10 ms, suggesting that the second part of the building was noticed slightly faster in this variant. The other AOIs in the PB_SUR_S variant include areas associated with the marine environment: stones, sea, path and background. The RC values for these AOIs vary, e.g. the area st_BA_PB_SUR_S (stones) achieved RC = 13.33%, while se_FR_PB_SUR_S (sea) showed RC = 60.00%. Furthermore, the DT, FFD, DAF and TTFF metrics for the sea-related AOIs indicate that although a smaller proportion of participants noticed these areas, the time spent looking at them was relatively long, indicating the additional stimulus provided by the sea element in the visualisation context.

The AOI metric values obtained for the identified areas of interest allowed a detailed analysis of the focus of attention on specific parts of the visualisation. Focus is associated with certain human responses, including interest in a particular visualisation element, but its nature (positive, negative) remains unclear. Therefore, the frontal asymmetry index was analysed for the defined AOIs, based on electrical brain activity (EEG) measurement. EEG recording at 500 Hz enabled dynamic changes in the activity of the hemispheres to be captured, making it possible to determine whether a given area evoked an approach or avoidance motivation. As a result, it was indicated which parts of the building visualisations attracted attention more engagingly, providing valuable information on the mechanisms of visual perception in an architectural context. Fig. 7 shows the FAA values obtained for each AOI, for the modified design options A (mountain scenery) and B (marine scenery).

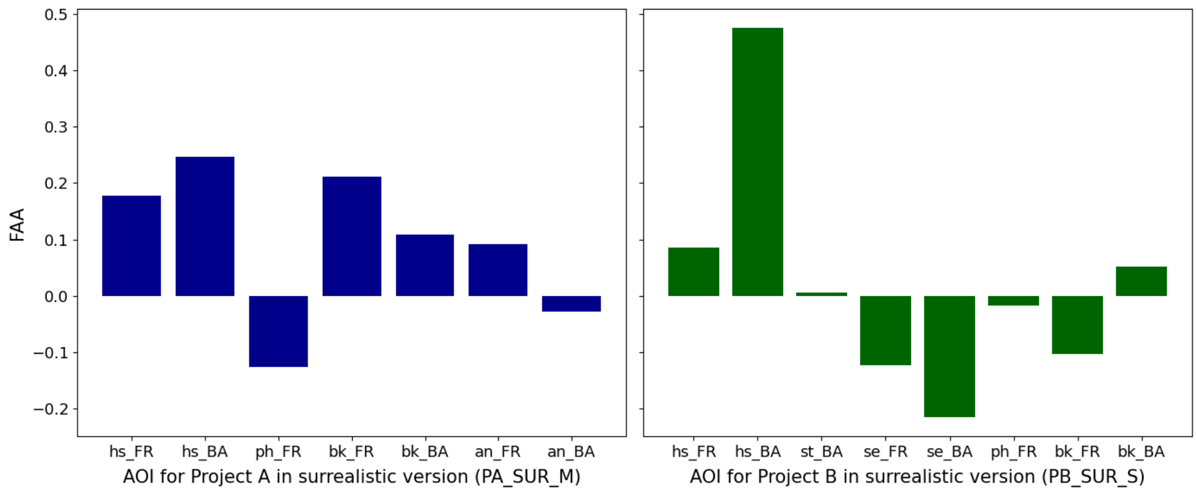

Figure 7. Mean FAA values for AOI in the surrealistic versions of Projects A (PA_SUR_M) and B (PB_SUR_S)

Source: own elaboration.

For project A, the results indicate that in the surreal mountain variant (PA_SUR_M), the respondents showed positive motivational reactions towards the main components of the visualisation, namely the building and the background. The FAA value for the building in front was 0.177, while that for the back was 0.247. For the background, the values were similarly 0.211 and 0.108. In contrast, the AOI corresponding to the path, denoted as ph_FR, had a value of –0.126, indicating a avoidance motivation this part. The FAA values for the animal-related AOIs indicate minimal, almost neutral (0.092) or slightly negative responses (–0.028).

For Project B in the marine scene, the FAA values indicate that the building body evoked an approach motivation in this case. A particularly strong one was registered for the view from the rear, more glazed side, for which FAA = 0.475. A slight positive response (0.052) was still obtained for the marine background from the rear of the building. The other AOIs associated with the aquatic environment showed clear avoidance motivation. Interestingly, the sea's lowest FAA values were obtained: –0.124 and –0.215. Slightly better for the background (sky) visible from the front of the building (–0.103). In contrast, there were relatively neutral values for the AOIs covering the stones (0.006) and the path (–0.017).

The FAA results obtained for both projects suggest that modifying the surrealist variants' surroundings significantly affects how viewers process visual stimuli. In design A, the mountainous environment promotes a more intense focus on the main elements of the building. In contrast, design B induces a clear the other AOIs associated with the aquatic environment showed clear avoidance motivation aspects of the environment while varying the perception of individual parts of the visualisation.

5. DISCUSSION

The results of the analyses indicate that introducing surreal scenery elements can significantly affect the perception of architectural visualisations. However, this effect is not universal. While in the case of the PA project, the addition of a mountainous landscape increased emotional arousal (measured by both the number and amplitude of GSR peaks) and intensified the approach motivation (higher frontal asymmetry index alpha), in the PB project, an analogous modification introducing a marine setting resulted in a decrease in arousal and no significant increase in FAA. Such discrepancies support the assumption that not only the surrealism of the surroundings determines the viewer's engagement but also the specific nature of the design (form of the massing, elements of the surroundings) and the perception of the particular landscape. The literature on visual perception of real estate and neuromarketing (Biercewicz et al., 2022; Borawska et al., 2022; Ogonowski & Piwowarski, 2024; Ramachandram & Hirstein, 2007; Vartanian et al., 2015) repeatedly emphasises that factors such as stimulus novelty, stylistic coherence, or emotion-laden cues can elicit varying psychophysiological responses. Similar relationships have also been observed in research on user interfaces in the context of e-learning, where psychophysiological analysis has identified the impact of visual design on information processing and user engagement (Piwowarski et al., 2024). Our study confirms these findings, showing that a house in the mountains (project PA_SUR_M) was perceived as more expressive or exciting, as reflected in the GSR indicators and higher FAA values. In contrast, the house by the sea (project PB_SUR_S), although intended to be equally intriguing, did not generate a significantly positive response, indicating instead the neutral or calming nature of the seascape as depicted.

Complementing these findings, the eye-tracking results show that in the PA_SUR_M project, respondents were more likely to gaze on the building visualisation (higher FC values) and spend more time on it (DT). This may indicate a clear interest or need to process the visual experience more thoroughly, which correlates with the elevated level of emotional response in the GSR. In the PB_SUR_S project, this phenomenon took the form of reduced interest, although the time to first fixation (TTFF) confirms that the coastal landscape is registered quite quickly. These results are reminiscent of the concept of so-called visual habituation or, conversely, intensification of attention due to a surprising or unique stimulus (Lin & Li, 2023). In our case, the mountains may have had a more substantial surprise effect than the calm sea.

The memory index (MI) analysis revealed significant differences between the variants. In the PA_SUR_M design, the MI value was significantly higher than in the PA_STD, indicating better encoding of visual information in the presence of a mountain landscape. For PB_SUR_S, the MI value was higher than for PB_STD, although this effect was not as strong as for PA_SUR_M. This may suggest that although surreal surroundings can increase the memorability of a design, its effectiveness depends on the type of landscape and the degree of fit with the building body itself.

It is also worth noting that the analysis of the AOI metrics provides information on visual exploration. The PA_SUR_M variant had a higher percentage of respondents who paid attention to key elements of the building, implying a stronger focus on the architecture in a surreal context. In the case of PB_SUR_S, there was an increased interest in the elements of the surroundings, particularly the water, which may have distracted from the body of the building itself. In addition, FAA analysis for the AOI showed that in PA_SUR_M, areas related to the building body elicited stronger approach motivation than in PB_SUR_S, where the focus of attention was more diffuse.

The higher frontal asymmetry alpha in the PA_SUR_M variant can be interpreted in the context of Davidson's theory (Davidson, 1992, 1993, 2004), according to which greater left frontal hemisphere activity signals an approach motivation, typically to positive or desired stimuli. These observations reinforce the hypothesis that a surreal environment, if visually and emotionally engaging, can enhance the perception of the whole project.

However, it is worth emphasising that the effects discussed do not apply to the whole population, and individual preferences may become apparent on a larger scale. The study included a group of 32 subjects, which is a reasonable starting point for GSR and EEG analyses. Still, in future work, it would be helpful to expand the sample and consider potential moderators (e.g. whether the respondent prefers the mountains or the sea in their daily life and what their aesthetic style is).

Compared to other studies on architectural visualisations, this study focuses on analysing the surreal environment of single-family homes. Furthermore, the applied integration of physiological measurement methods (EEG, GSR, eye tracking, FEA) distinguishes this work from other studies. This is particularly evident in the context of selected indicators such as, for example, EEG frontal asymmetry (FAA), memory index (MI) or eye tracking AOI metrics. The data not only clarify whether surreal surroundings affect perception but also indicate how and why specific modifications can change the emotional and motivational response of the viewer. This approach places the work at the intersection of research fields such as neuroaesthetics, neuromarketing and visual merchandising design. Thus, the presented research complements the subject literature and indicates potentially new research perspectives.

6. CONCLUSION

Research has confirmed that the way architectural visualisations are presented is important to the audience and can influence their emotions, attention, and memory of the design. Using surreal elements in the visualisation environment does not always lead to clear-cut effects. Their effectiveness depends on stylistic consistency with the presented building. Psychophysiological analyses (GSR, EEG, eye tracking) have shown that introducing specific modifications can enhance emotional responses and cognitive engagement. Still, this effect is not universal and depends on the visual context.

The research provided valuable information for architects and property visualisation developers. The right scenery fit can intensify positive emotions, increase viewing time, and enhance design recall. In the context of real estate marketing, this can mean more effective visual materials. However, these effects should be carefully tested, as an ill-fitting setting can undermine a project's perception. The results also suggest the need to consider individual audience preferences, which may further influence how visuals are perceived and evaluated.

Despite the essential findings, limitations of the study, such as the sample size and the lack of analysis of individual preferences that may shape responses to different settings, should be considered. Future studies should consider a broader range of landscapes (e.g. urban, perhaps more futuristic) and apply more complex statistical analyses to determine the influence of individual factors more precisely. Further exploration of this issue may lead to even more effective architectural visualisation strategies that integrate aesthetics with perceptual psychology and the development of tools to support purchasing decisions in the real estate market.

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APPENDIX A

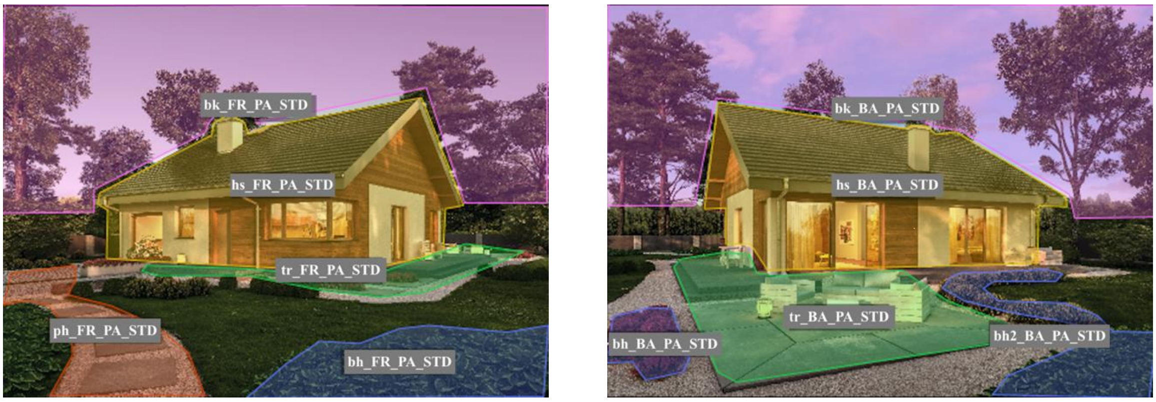

Figure A1. Areas of Interest for the PA_STD project version
Source: compiled from: projekty.muratordom.pl.

Figure A2. Areas of Interest for the PA_SUR_M project version
Source: compiled based on: projekty.muratordom.pl.

Figure A3. Areas of Interest for the PB_STD project version
Source: compiled from: projekty.muratordom.pl.

Figure A4. Areas of interest for the PB_SUR_S project version
Source: compiled based on: projekty.muratordom.pl.