

# INTRODUCING GREENERY INTO A BUILDING BASED ON ITS IMPACT ON HUMAN WELLBEING – REVIEW OF THEORIES AND METHODS IN ARCHITECTURE

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Received: 25.05.2023; Revised:16.11.2023; Accepted: 15.12.2023

## Abstract

The presence of greenery around and within buildings is an integral aspect of architectural space. Although scientific knowledge regarding the impact of greenery on human well-being is expanding, there remains a scarcity of guidelines for implementing this knowledge in architectural design. This review article aims to lay the foundation for further research dedicated to supporting architectural design in the seamless integration of greenery as a co-creative element within human living space. Existing review literature is diverse and dispersed across various scientific disciplines, addressing distinct objectives, approaches, and research methodologies. Consequently, this review initially concentrates on an in-depth exploration of the broad topic of perception in architecture, highlighting significant theories and methods. Subsequently, the analysis extends to the current state of research specifically centred on well-being and the perception of greenery in the built environment. The evaluation emphasizes criteria conducive to obtaining objective, quantitative results. Finally, considering their stages of development, the available research methods are categorized and those most pertinent to the field of architecture are identified.

**Keywords:** Perception of greenery in architecture; Sustainable architecture; Wellbeing design in architecture.

## 1. INTRODUCTION

The positive impact of plants (commonly referred to as greenery) on human health and well-being is widely acknowledged. Some of the beneficial properties of greenery for humans can be substantiated using quantitative values. This includes, for example: the ability to regulate air temperature and humidity, reduce carbon dioxide levels, neutralize pollutants, or provide noise protection. However, individual human experiences resulting from contact with greenery remain relatively underexplored [1]. Although intuitively we sense the importance of natural elements for human

well-being, the reality of urban investment policy does not favour it. The measurable, significant economic value lies in a square meter of an apartment, office, or parking, rather than in squares, flower beds or garden plots. Guidelines on sustainable urban development unequivocally emphasize the need to increase both the quantitative and qualitative presence of green spaces in urban areas. Nevertheless, according to the development forecasts for many large cities, the quantitative balance of undeveloped areas is expected to decrease. The processes of densification of existing structures, development of post-industrial areas and utilization of urban wastelands are evident. The

abovementioned implies reduced opportunities for the expansion of organized green spaces in open areas. Therefore, efforts should focus on the implementation of greenery in small available spaces in public areas, in the immediate vicinity of buildings, and within their interiors.

The objective of the study undertaken by the authors is to delineate a research direction aimed at developing methods of designing greenery experienced in the vicinity of the building and its interior, in a manner that would enable the optimal utilization of its beneficial impact on the psycho-physical state of humans. Conclusions in the form of specific design guidelines or methods supporting the design process in this regard would be valuable for urban planners, architects, interior designers, as well as authors of legal regulations concerning architectural spaces and the users of these spaces. The first essential research step presented in this article is the exploration of the broader theme of the impact of greenery on human perceptions. Research in this area is diverse and scattered across various scientific domains. These studies differ in their objectives, approaches, and research methods, although there is an increasing tendency to integrate them and seek common ground.

This paper serves a review purpose, aiming to lay the groundwork for further research into the possibilities of supporting architectural design by integrating greenery as a co-creating element of human living spaces. Although there are existing review works related to the impact of greenery on humans [1] [2], they are not numerous, and their objectives, scope and approaches vary. They do not form a solid foundation for future research planned by the authors. This article classifies the existing knowledge regarding the impact of greenery on human perception and identifies the trends in its development. An attempt has been made to answer the following questions:

- which issues have been best recognized so far,
- to what extent has the knowledge about them been scientifically proven, and implemented in the theory and practice of architecture,
- what research methods are being used,
- which of them offers the greatest hope for further development.

The method of literature source analysis was employed. To systematize this approach, the study initially addressed the broader topic of the perception of architectural space in general, considering the greenery as its integral element. Due to the extensive scope of the subject matter, this part of the review is

synthetic, emphasizing the most significant theories and methods. Subsequently, the state of research aimed specifically at the perception of greenery in the built environments and interiors was analysed. Given the smaller pool of sources, this review is more detailed. The key criteria for the analysis included the potential for obtaining objective, possibly quantitative results, and their relation to architectural issues. Then the available research methods were categorized considering the stages of their development. On this basis, conclusions were drawn regarding the current state of knowledge and possibilities for its further development to optimally harness the potential of greenery in the daily environment of humans.

## 2. PERCEPTION OF SPACE IN ARCHITECTURAL THEORY

The first treatises on buildings and architectural space fall within the intersection of philosophy and architectural theory. The works by ancient, medieval, and Renaissance thinker-architects (e.g. Vitruvius, Alberti, Vignola, Palladio) mainly addressed the principles of harmony, proclaiming the superiority of certain geometric proportions over others. These works attempted an objective explanation of the preferences found in specific proportions and forms. They remained faithful to the claim that beauty is something objective, independent of the observer. As St. Augustine proclaimed, something is beautiful not because it is pleasing, but it pleases because it is beautiful. Simultaneously, the first subjective themes emerged, emphasizing the importance of the form in relation to the human eye (e.g. Basil of Caesarea) and the role of habituation in art perception. During the Renaissance and Baroque periods, objectivist concepts prevailed, and it was not until the 18<sup>th</sup> and 19<sup>th</sup> centuries that theories combining both subjective and objective elements developed. Advances in understanding the human nervous system and associated processes reinforced the importance of the subjective aspect in perceiving architectural space.

In the 20<sup>th</sup> century, industrial civilization and the growing importance of technology led to the dehumanization of the human environment (increasing scale of cities and buildings, urban sprawl, standardization). Concurrently, an anthropocentric ethos solidified, granting humans a superior position. This is reflected in the Modulor developed by Le Corbusier (a leading contributor to the theory of modernism in architecture), a contemporary reinterpretation of Vitruvian Man [3] serving as a proportional system based on

human dimensions. Both Leonardo da Vinci's renowned drawing and the modernist Modulor can be viewed as analyses of the human body, facilitating an understanding of the spatial scale needed for a human comfortable life. An alternative interpretation is to treat them as an aesthetic model capturing the beauty of geometric relationships and the mysterious connection between humans and the world. The practical understanding associated with the first interpretation gave rise to modernist initiatives such as urban visions of "healthy cities", functional approaches in designing cities, settlements, and buildings as well as ergonomics - the science of planning and dimensioning space and objects to be safe and comfortable for humans. The second, immaterial understanding of space and its impact on humans is more challenging to comprehend. Research in psychology, firmly established as a scientific discipline only in the 19<sup>th</sup> century, has been particularly helpful in this regard. They allowed for a better understanding of cognitive mechanisms, including perception. A notable example is the work of John Dewey in the 1920s and 1930s [4] emphasized the complexity of aesthetic experience, engaging the whole person, their thoughts, emotions, and senses. He argued that aesthetic experiences are part of the natural processes with which the human being is fundamentally connected, and aesthetic experience represents the highest form of this interaction. One noteworthy attempt to translate psychological theories into architectural theory was made by Polish architect Juliusz Żórawski [5]. Using the theory of character psychology, he identified certain types of forms and compositions as more legible to humans than others, thereby linking psychological knowledge of perception with historically grounded principles of architectural aesthetics.

Architectural theory has also been influenced by the currents of semiotics and semiology (considered part of social psychology) concerning the impact of signs and symbols [6] on the perception of space and the construction of its meaning. This theme, among others, was addressed by Christopher Alexander [7], postulating a return to spatial structures traditionally shaped, retaining human scale and employing archetypal forms of urban planning and architecture. He further elaborated on this concept in subsequent works, rejecting the functionalist model of the built environment in favour of considerations centred on beauty and form. Kevin Lynch is considered the founder of the theory of the image of cities, defining its basic structural elements [8]. These elements define the compositional arrangement of a city, thus linking

to material objects (e.g. streets, squares, buildings, monuments, green areas) while simultaneously being parts of the so-called visual code. A slightly different perspective on the selection of these elements was presented by Christian Norberg-Schulz [9], Gordon Cullen [10] and Kazimierz Wejchert [11], although all of them, like Lynch, referred to visually perceived elements. These theories, although still acknowledged in the world of architects and urban planners, have been criticized by psychologists as not relating to existing concepts of multisensory cognition [12]. Focused on visual aspects, they did not consider intangible objects or the memory and identity of places.

Research at the intersection of sociology and psychology addressing the social and cultural dimensions of space has proven crucial for the development of theories related to the perception of architectural space. An exemplary instance is [13] the theory, of four categories of distances within which diverse human interactions occur (this is one of the few studies that give a specific rationale for spatial dimensioning). Additionally, theories on the formation of mental maps have proven valuable. In the realm of architectural psychology and urban sociology, these represent a cognitive encoding of space within the human mind. This representation goes beyond mere replication of existing environmental elements, it also involves the valorisation of attributed values. This approach towards urban space was adopted by Jan Gehl [14, 15]. He attempted to correlate the quality of life in urbanized areas with the characteristics of the spatial structure, the physical environment (e.g. temperature, air movement, light) and social interactions. A contemporary continuator of this trend is David Sim [16].

The psychologically related foundation is also evident in the theories of architects such as Steen Eiler Rasmussen [17], Juani Pallasma [18, 19], and Peter Zumthor [20]. Their works exemplify more or less analytical reflections that integrate elements of contemporary human knowledge with their own observations and design experiences. A common thread among all these authors is the multisensory perception of architectural space, unaccounted for by Lynch, who primarily attributed it to visual stimuli. The theories of Rasmussen, Pallasma and Zumthor align with the contemporary trend in psychological and neuroscientific research, suggesting that we perceive our surroundings not through contingent senses separately, but through strongly intertwined perceptual events [21].



The most objectified, yet practical dimension, is demonstrated by the studies linking psychology to the architecture of a specific type of facility. The largest collection comprises research focused on the perception of space, conducted for the need of healthcare facilities. They were pioneered by Roger Ulrich [22] [23] and had found continuity, for example, in the works of John Zeisel [24, 25], Eve Edelstain [26] and Tanja Vollmer [27]. In their cases, a more in-depth methodology is employed compared to the majority of the previously mentioned works. They are based on profound observations, interviews and surveys conducted on specific groups of people. These studies provide evidence of the connection between the features of the spaces where patients were located and specific effects on their psychophysical well-being. Studies of a similar character, although to a lesser extent, have also been conducted for educational and office spaces.

New opportunities for studying the impact of space on individuals have been brought on by advances in neurobiology, coupled with new technological capabilities for monitoring the human nervous system, particularly the brain. These advancements allow the observation of how the human brain activates in response to various sensations, including those related to aesthetics [28, 29]. So far, attempts to apply new neuroscience methods in the field of architecture are pioneering. They serve cognitive purposes, expanding our knowledge about brain function and research methodologies. However, they are not yet developed enough for practicable purposes, for example, related to architectural design.

### 3. THE IMPACT OF GREENERY ON HUMANS IN ARCHITECTURAL THEORY AND PRACTICE

Greenery in the human environment, both in urban interiors and building interiors, should be considered an integral element of architectural space. This approach has roots in the history of architecture. Rows and groups of trees or shrubs and large, individual plants, considered “volumetric” elements, can be treated as complementary forms, or even as co-creating of the architectural composition. This formal and visual approach dominated the theory of historical architecture. However, it is important to note that historical periods provided greater opportunities for building a relationship between humans and nature due to factors such as small-scale human settlements, and natural characteristics of construction technolo-

gies. Consequently, more deeply than contemporaries – people in those times were immersed in the natural world, capable of creating a healthy environment through observations of the surrounding nature and the transfer of experiences from generation to generation [30]. It can be asserted that they did not necessitate an exploration of the impact of greenery on humans in the discussed aspect, as they did not experience its absence. The awareness of greenery as an element of a human environment increased in the theories of modernism when industrialization distanced people from nature. Sunshine, greenery and air were singled out by Le Corbusier [31] as a kind of triad of essential elements in both buildings and urban spaces. Greenery was recognized, therefore, as more than just an aesthetic element, and was included in the functional program of so-called healthy cities as recreational space and an essential environmental component for humans. Its climate-forming role at the city scale was also acknowledged, influencing planning decisions regarding open green space systems and ventilation corridors. This approach continues to be developed and is predominantly represented in scientific works dedicated to greenery in the fields of architecture and urban planning, with a significant focus on compositional and utilitarian issues considered at the urban scale [32, 33].

The trigger for further changes in the approach to greenery came from the pro-ecological trends, which in the second half of the 20<sup>th</sup> century were integrated into the concept of sustainable development. Conclusions of catastrophic environmental reports and pessimistic forecasts for humanity made people realize that humans are not rulers of nature, but an integral part of it. In understanding architecture, it became essential to shape its relationship with the environment, especially with its natural elements. A need has emerged for a broader perspective on the role of greenery in the human environment than ever before. The most recent interpretation of this role is the systematic categorization of ecosystem services provided by natural elements [34]. It speaks of four fundamental groups of services: basic (sustaining the functioning of ecosystems), productive (related to the provision of food, water, and raw materials), regulating (related, among other things, to the improvement of climate quality, protection of air, water and soils) and cultural. The latter, the least obvious group, encompasses values related to aesthetics, ethics, cultural identity, educational values, inspiration for the arts, recreation, and the significance of the physical and mental health and well-being of humans.

A very substantial proof of the importance of the human-building-environment relationship came out in the second half of the 20<sup>th</sup> century with a phenomenon known as Sick Building Syndrome SBS [35] [36]. It allowed to prove the correlation between the fact that people regularly stay for a significant part of the day indoors without contact with the natural environment (for example, in air-conditioned spaces with limited access to daylight and the possibility of observing the surroundings through windows) and the consequences for their health. These consequences were measured, for example, by susceptibility to specific diseases, the number of sick leaves or the occurrence of specific mood symptoms. Research on SBS focused primarily on issues related to ventilation, access to daylight and window views. Greenery issues have rarely been addressed, however, a 1990s study conducted in selected office buildings showed that SBS symptoms among employees were noticeably lower (on average by 21%) in spaces with substantial amounts of plants than in rooms without them [37]. It was also demonstrated that zones with visual access to windows overlooking a landscape with greenery had a better impact on employee health and wellbeing compared to those without such contact [38].

A significant area of research providing evidence for the positive impact of greenery on humans pertains to healthcare architecture, particularly hospitals. Initiated and developed since the 1980s by, the previously mentioned, Roger Ulrich [22, 39], these studies demonstrate that the presence of greenery in interiors and in views from windows accelerates the healing process and enhances well-being. He and his successors employed patient interviews as well as comparative data regarding, for example: recovery time, the amount of pain-relief medication administered, and various physiological responses. This body of research has directly translated into design guidelines dedicated to hospitals and healthcare facilities, especially applied in the United States and the United Kingdom. A similar approach can be observed in efforts to design spaces for children – preschools, schools, and public spaces in residential areas. Studies by researchers, mainly from the United States, Canada, the United Kingdom, and Scandinavia, have highlighted the significant role of contact with nature in children's development at various stages. The most beneficial role is attributed to the opportunities for outdoor exposure, with a lesser emphasis on the presence of plants indoors. Visual contact with the landscape from the interior and its

variability in the time of day and season of the year is also considered important [49]. The theme of greenery in the human environment also emerges in the context of office interior design. This development is driven by the growth of the labour market for the so-called creative classes [41], and environmental certification systems that have become important for the market value of office space. Most recognized certification systems take into account a set of criteria influencing the comfort and well-being of users. Attractive interiors with individualized character, including greenery (widely acknowledged as beneficial), have become a significant element in the corporate image of large companies. In many cases, unfortunately, it may overshadow the main goal related to ensuring the actual beneficial impact of greenery on people.

### 3.1. Biophilia and wellbeing in architecture

The hypothesis of biophilia was developed in the 1980s as part of evolutionary psychology. Erich Fromm initially used this term in the context of a psychological orientation toward biophilia, referring to an attitude that attracts everything that is alive and vital. The hypothesis of biophilia was formulated by Edward Wilson [42], suggesting that humans have an innate tendency to seek connections with nature and other forms of life. He asserted that fulfilling a biologically determined need for close contact between humans and nature determines their well-being. This need remained undisturbed in human evolution until the time of industrialization and its resulting consequences (migration of people to cities, expansion of the size of cities, increased reliance on technology in daily life, etc.). It is therefore necessary to create opportunities for realizing this need in contemporary conditions by means of a properly designed living environment, both within buildings and urban spaces. Biophilia, therefore, directly concerns architecture and urban planning [43, 44], emphasizing the significance of natural elements in the immediate daily surroundings of humans. These include natural climatic factors, flora, and fauna, but also natural textures, smells, sounds and even forms. According to biophilia, humans respond positively to real natural elements, as well as those exhibiting similarities to nature or depicting it. This aligns with Ulrich's research, demonstrating that patients experienced a positive impact not only from views of the actual landscape at the window but also from photographs of it, albeit to a lesser extent. Such far-reaching claims are not the subject of the Authors' research, it is essential to acknowledge that the field of biophilia



theory, has summarized existing research, providing scientific evidence supporting the association between the presence of natural elements in the human environment and the human well-being (notably the achievements concerning SBS and health care facilities). They became the scientific foundation linking biophilia to a broader research trend. They also inspired the research methodologies supporting the biophilia hypothesis. Although it is challenging to fully substantiate their validity through science, numerous indirect, partial pieces of evidence exist, with a significant portion focusing on the impact of greenery on humans. It has been noted, for instance, that similar conclusions about people's positive response to nature and its elements in an urban environment can be found in various studies regardless of the cultural context in which they were conducted [45, 23]. A parameter of interest to researchers related to the influence of greenery on humans has been found to be stress levels, the fluctuation of which can be measured through differences in blood pressure, muscle tension and skin conductance. An interesting overview of studies comparing the reactions of people (both healthy and ill) to views of real or visualized nature (in the form of photographs or videos with sound) versus views of cities or interiors devoid of any elements of nature was made by Roger Ulrich [39]. Both his own research and that of other authors confirmed the stress reduction effect in a relatively short time in response to being exposed to elements of nature for even a few minutes. Measurements of physiological responses and interviews with participants were employed. These studies, among others, contributed to the formulation of the Stress Reduction Theory (SRT), asserting that looking at scenery containing natural elements, such as greenery or water, evokes positive emotions and feelings, such as interest, pleasure and calmness. It has a regenerative effect, alleviating our state of alertness after a stressful situation. A related theory is the Attention Restoration Theory (ART), which states that visual contact with greenery and water enhances concentration by rejuvenating from a state of mental fatigue and inducing a state of awe [45, 46, 47, 48]. Similar to the studies on the impact of space on humans, significant potential is also evident in research specifically focused on greenery, employing methods from the field of neuroscience and the tools used to monitor nervous system reactions. Nevertheless, as previously noted, their application in the context of architecture and urban planning remains limited at present.

#### 4. DEVELOPMENT OF RESEARCH METHODS

From the research review presented here, conclusions can be drawn regarding the development of related research methods. In historical periods, the reliance was mainly on philosophy and logical methods, which allowed rationalizing observed phenomena, and connecting facts and theories from fields such as medicine, physics or biology. In architecture at the time, the predominant approach to greenery was as a formal element (composition, aesthetics, visual effects) and as a functional element (representational importance, potential for recreation, sports, etc.). A significant portion of the contemporary research on spatial perception in the disciplines of architecture and urban planning still relies on intuitive methods, observations, literature analysis, case studies and the integration of science with design practice through research-by-design method. Predominantly on abovementioned methods are based on the key works of Le Corbusier, Lynch, Alexander, Norberg-Schulz, Cullen, Wejchert, Rasmussen, Pallasma, Zumthor, Gehl or Sims that remain crucial to modern architectural theory. They are qualitative in nature and do not provide objective premises in the form of quantitative parameters.

The 20<sup>th</sup> century saw the emergence of themes related to psychology and sociology. Research methods based on experiments with specially selected groups of people were developed. Their reactions to specific stimuli were studied by means of questionnaires and interviews, along with visible changes in their behaviour. Over time, the methodology of conducting interviews, supported, among other things, by statistical knowledge, has significantly evolved, making survey results increasingly reliable. Well-known methodologies in architecture that extensively use enhanced interviews include, for example, the Post Occupancy Evaluation (POE) method, which allows for the qualitative assessment of existing buildings [49, 50]. Most of the studies mentioned in this article at the intersection of psychology, sociology and architecture are based on surveys, interviews, and in-depth observation, such as Hall's research, most of the works of Ulrich, Kellert, Edelstain, Vollmer and the research underlying the Stress Reduction Theory (SRT) and Attention Restoration Theory (ART). Such research has a qualitative character, but is also largely quantitative due to the statistical processing of survey data. Another group comprises studies based on objective measurements of body reactions. Examples of such

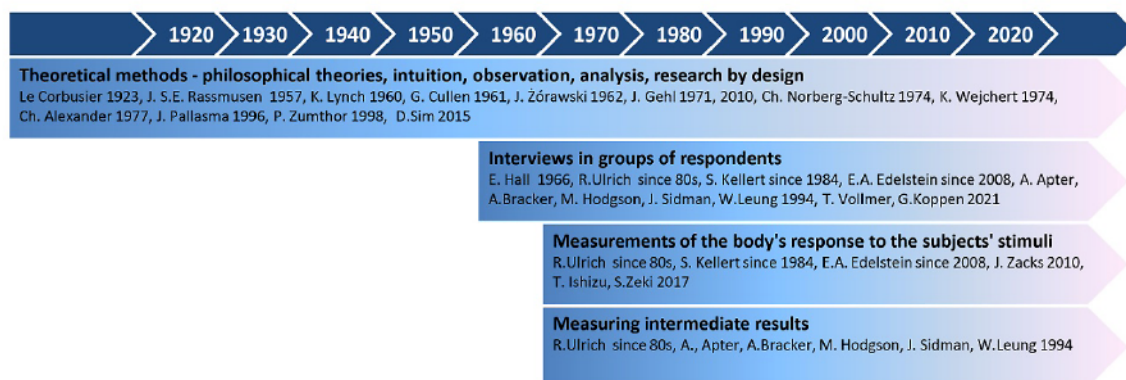


methods can be found in the studies of Ulrich [39, 51]. They provide quantitative results. A significant limitation of studies of this type was the difficulty in conducting them. Thus, they initially involved small groups of people and limited situations. Technological progress in recent years has significantly changed this situation, allowing for increasingly accurate and comprehensive measurements of human bodily reactions. Monitoring heart rate (ECG, smartwatch), skin reactions (GSR), eye movement (Eye Tracking), and brain responses (EEG, fMRI) is becoming less burdensome for participants, and some devices are portable. This greatly expands the possibilities in terms of the situations, locations, and duration of measurements. Currently, the utilization of these methods regarding the impact of architectural space on humans is minimal. One of the major barriers is the need to integrate architectural experiments with highly specialized biomedical knowledge in terms of research assumptions, including interpretation of the results. While still a major challenge, it represents considerable potential for the future, as justified, for example, by Eve A. Edelstein and Eduardo Macagno [2] in the publication “Form follows function: Bridging neuroscience and architecture”.

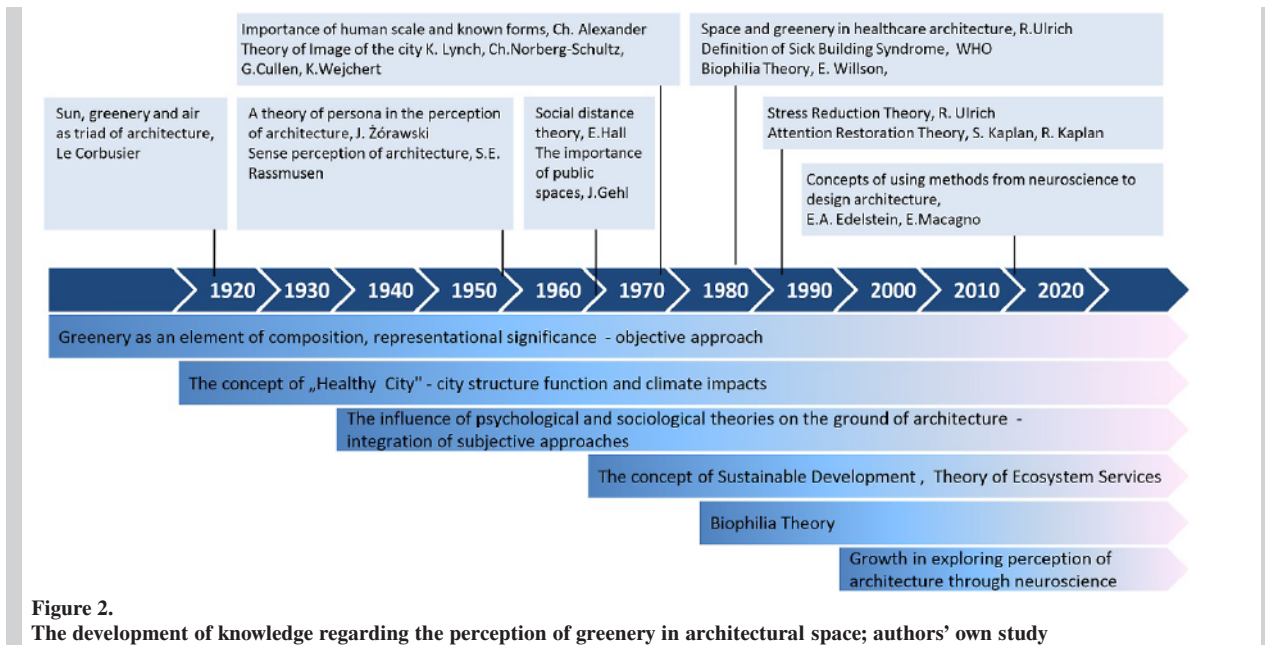
Another set of parameters analyzed in the context of the impact of greenery on humans measures the intermediate outcomes. In the case of studies on patients, these may include the amount of medication taken or recovery time, in studies on office workers, it could be the susceptibility to certain diseases, and the amount of sick leave, while in the studies on students – academic performance, attendance, the number of conflict situations requiring the intervention of caregivers, and in the studies in residential environments – data on crime may be considered. These parameters are developed as a comparison between

two groups of people: those who had contact with a specific element of space, such as greenery, and those who did not. These methods were used in the aforementioned Sick Building Syndrome studies, focusing on healthcare and education architecture. The results obtained through this method are quantitative in nature. Big Data resources open up new possibilities for parameterizing intermediate results [52]. Firstly, there is access to much larger information resources, both in terms of type and quantity. Increasingly, previously inconspicuous data, such as the nature of people's movement recorded by various types of traffic-related sensors, or the popularity of specific places measured by the quantity and character of photos posted on social media becomes a source of knowledge [53]. This allows for a deeper understanding of spatial perception, the verification of existing theses, and the observation of changes resulting from new habits. Meanwhile, computational methods based on machine learning or neural networks enable the analysis and deciphering of the regularities and trends in large sets of seemingly chaotic data.

Therefore, a division of research methods into four groups of methods is drawn: intuitive-logical, interviews, bodily parameter measurements and intermediate results. Their development over time is illustrated in Figure 1. All these methods are still in use today, although their roles change over time. Intuitive-logical methods, prevalent in historical periods, are now insufficient due to limitations in obtaining quantitative data and objectifying results. They are rather applied in combination with other methods, mainly in preliminary studies. There is a noticeable process of improving research methods in the area of interviews, intermediate results and, in particular, measurements of body reactions.



**Figure 1.** Development of research methods to assess the impact of green spaces on the human experience; authors' own study



## 5. SUMMARY AND CONCLUSIONS

The development of knowledge regarding the perception of greenery in architectural space can be presented as a process of complementing the historical, primarily aesthetic approach with new elements (Figure 2). The period of the last few decades has necessitated the consideration of an increasing number of factors. Treating greenery merely as a visual “setting” for practical issues is no longer sufficient. The acquired knowledge from other scientific disciplines (e.g., psychology, sociology, neurobiology) sheds new light on the nature of human-environment relationships.

The positive impact of greenery on human well-being is widely recognized as an obvious fact. It can be argued that the existing body of scientific evidence, most comprehensively systematized to date in relation to biophilia theory (though not exclusively), confirms this fact. However, the nature of this evidence remains at a very general level. Based on this, we know that people generally respond positively to the presence of greenery in their environment:

- being in open green areas,
- being indoors with access to greenery in the form of a view from the window,
- being indoors with living greenery present,
- being indoors with visualized greenery.

Whereby, the strength of this influence follows the order of the listed forms of exposure. Therefore, the

more direct and complete the contact with the natural landscape, the greater the impact. Existing research, however, does not provide a rationale for more detailed conclusions than the suggestion that providing people with contact with greenery in the architectural spaces where they live every day is advisable. It is unknown how to design greenery in the immediate surroundings of humans to best leverage its positive role. The rationale on this topic is insufficient and imprecise, not allowing a clear determination, for example, of the distances from human living areas where vegetation should be located, the forms it should take, or how to choose it. There are also numerous questions emerging about the potential use of virtual reality as a substitute for real greenery.

The justification for the lack of unequivocal design premises in this regard may be the difficulty in obtaining strong scientific evidence. Qualitative studies, predominant in the disciplines of architecture and urban planning do not provide such evidence. On the other hand, studies delivering quantitative results are challenging to interpret conclusively. Howard Frumkin (2008) aptly explains this in the chapter of the book “Biophilic design” entitled “Nature contact and human health: building the evidence base”. He compares studies on the impact of contact with greenery on humans with studies [54] on the effects of drugs. In the case of drugs, it is known which substance and in what dose was administered, so the stimulus is very precisely defined. The reaction, as well, can be described and measured, but individual



characteristics (such as genetic predispositions) and momentary conditions (mood, health) may influence it, making its quality as scientific evidence debatable. In the case of studies on the impact of factors such as greenery, both the stimulus and the response are something that is challenging to isolate as something unambiguous and repeatable. However, it seems that the latest technological capabilities in studying human reactions will minimize this problem, among other things, by increasing the number of subjects, the diversity of situations and the monitoring time.

Therefore, there is a significant need to develop existing knowledge and create premises for specific actions supporting the design of architecture and greenery, taking this criterion into account. To achieve this, interdisciplinary action is necessary, combining architectural and landscape architecture issues especially with those in the field of psychology and neuropsychology. It seems that this research should develop in two directions. Firstly, in the direction of the possibility of developing guidelines for designing greenery in the immediate vicinity of buildings and their interiors resulting from the criterion of utilizing their impact on the psycho-physical state of users. However, this will be challenging due to the number of conditions that make each design situation unique. Therefore, the expected results may involve very general design recommendations.

A second direction could be the development of a design methodology with the participation of future users. This option, although seems poorly adapted to the current investments' realities, follows the future trends related to products personalization. It potentially can prove useful, especially in the case of interior design. For both, the first objective (general guidelines) and the second objective (design methodology with the user), virtual reality as a simulation of various design variants may be useful [55, 2]. Although it does not reflect the full sensation of real contact with nature, according to existing scientific premises, there are strong analogies between the effects of both realities on humans, including in the case of greenery.

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