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Review Article

A review of the Effects of the Physical Components of the Interior Space of Architecture on Emotions with an Emphasis on Neuroarchitecture

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Abstract

Problem statement: Mental health has received a lot of attention in recent years from various fields. One of the parameters of mental health is emotion, which has been influenced by various environmental, social, cognitive, and motor factors. Architectural space as one of the important environmental components has an impact on emotion and has neurophysiological effects on the human brain. Since humans spend a lot of time in the interior of architecture, it has doubled in importance. Despite the great importance of this issue, little research has been done in architecture so far, and most of the research has used qualitative methods of interview, observation, and questionnaire, which, due to the influence of the author, there has been a possibility of orientation in the results. Nevertheless, with the advancement of technology and the emergence of the field of neuroscience, new quantitative tools and methods have been provided to researchers to measure emotion, and it has led to the formation of a new paradigm of neuroarchitecture.

Research Objectives: The present research aims to review the studies conducted in this field so that in addition to clarifying the effect of interior architecture on emotion, the methodology of the studies is also analyzed and provides a clear path for future researchers. Therefore, the present research questions can be expressed as follows: Which physical components of the interior space of architecture affect emotion? What effect has their exposure had on neurophysiological emotion? And how do these emotions appear?

Research Method: The present research employed the systematic review methodology. In this regard, the inclusion criteria such as terms, measurement variables, measuring instruments, and publication date were defined. The way of searching databases of studies, selecting and assessing their qualities were defined, and the final studies were introduced and analyzed.

Conclusion: The results indicate the effect of the physical parameters of the interior space such as form, materials and texture, furniture, ceiling height, architectural details, and openness to nature on emotion, each of which is one of the emotional states and feelings such as enjoy, pleasure, arousal, and disgust have appeared. The present research is a window to the issue of mental health, which introduces a field for using the interior space of architecture as a type of treatment or prevention.

Keywords: Systematic review, Emotion, Physical components, Interior space, Neuroarchitecture.

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Introduction

In recent years, the topic of mental health has become very important (AIWH, 2018). Emotion is one of the main parameters affecting mental health (Williams, Watts, Macleod & Mathews, 1988). Watson (1913) was the first to invite psychologists to study emotions and other internal experiences (Watson, 1913). After those years, the study of emotions was accepted and started expanding (Dorn, 1998). Since then, emotion has played a fundamental and important role in the life history of people and their mental health (Fruzzetti & Erikson, 2010). Emotions are internal data that affect behavior (Wells & Mathews, 1994). That is, the human body can respond to a stimulus before it can consciously process the input (Öhman, Flykt & Lundqvist, 2002), and sometimes this happens without the intervention of the visual cortex (Liddell et al., 2005). In addition, emotion can affect human health by affecting the inflammatory response of the immune system and indirectly affecting health-related behaviors (Kiecolt-Glaser, McGuire, Robles & Glaser, 2002). Therefore, to achieve mental health, the emotion parameter cannot be ignored due to its great and unconscious influence.

Along with the subject of mental health and emotion theories, the term "Behavior setting" was formed in the field of environmental psychology to describe the impact **of** physical space (time, place, and objects) as well as the social environment (the activity patterns of others) on behavior (Barker, 1978). Therefore, several studies in the field of social sciences have investigated whether the built environment affects our mental health and emotions (Evans & McCoy, 1998; Ferguson & Evans, 2018; Papale, Chiesi, Rampinini, Pietrini & Ricciardi, 2016), and generally, they have used indicators of psychological impact through self-evaluation rating scales, questionnaires, and explanations (Dazkir & Read, 2012; Dinis, Duarte, Noriega, Teixeira & Rebelo, 2013; Küller, Ballal, Laike, Mikellides & Tonello, 2006; Roessler, 2012). However, the investigation of this issue has been neglected in the field of architecture while humans spend a lot of time in the interior of architecture (Klepeis et al., 2001).

Therefore, an investigation **into** emotions towards the environment, which is in the field of environmental psychology, can be effective in identifying the impact of the interior space of architecture on mental health (Shiota & Kalat, 2012). Recently, neuroscience studies have tried to fill the gap between architecture and environmental psychology by describing some basic mechanisms and **trying** to clarify the impact of architectural space on emotion using new instruments (Nanda, Ghamari, Pati & Bajema, 2013), which has caused the emergence of a new paradigm called neuroarchitecture. The field of neuroarchitecture uses neuroscience tools to investigate the effects of architecture on its inhabitants (Edelstein, 2008). Therefore, the aim of the present systematic review is to identify the set of experimental studies with specific criteria related to the impact of interior architecture on emotion using neuroscience and to clarify the mechanism of this impact.

Research Questions

Considering the importance of the effect of interior architecture on emotions and as a result on human mental health, the present review question can be expressed as follows:

Which physical components of the interior space of architecture affect emotion? What effect has their exposure had on neurophysiological emotion? And how do these emotions appear? The present research is a systematic review to clarify the effect of interior space stimuli on emotions and take a step towards creating human mental health.

Research Hypothesis

As a multi-dimensional being, man is influenced by many environmental factors that affect his mental health. One of the factors that people spend a lot of time on is the interior space of architecture.

It is assumed that by placement in the interior space of architecture, the human being is affected by physical and mental components and this effect causes changes in the human being, which is also effective in mental health.

Research Methods

The present research was conducted using the systematic review method (Higgins & Green, 2008) and with the aim of searching and defining the scope of research on the effect of the physical components of the interior space of architecture on emotion using neuroscience. This issue is important because humans spend a lot of time in the interior of architecture; therefore, the present review specifically deals with studies that have investigated how the interior of architecture affects neurophysiological emotion. It can be said that in a systematic review article, the latest scientific information on a specific subject is reviewed and the purpose of writing a review article is not only information but also evaluation and interpretation. Therefore, in the present review, the results, methods, instruments, and other information of the studies have been analyzed and compared. In relation to the effect of architecture on neurophysiological responses, search terms, inclusion, and exclusion criteria are defined and presented below.

Theoretical Foundations and Literature Review

• Emotion

The word "emotion" from the Latin root "Motere" means to move, and the addition of the prefix e gives it the implied meaning of "going away" (Golman, 2002) and literally refers to any stimulation or disturbance in the mind, feeling, affect and powerful or excited mental state are considered (Schultz, 1976). Operational and conceptual definitions of emotion have been faced with a wide range of meanings throughout history. Gartner (2012) defines emotion as one of the psychological processes such as perception, memory, cognition, feelings, and behavior of a person, which can be measured by special sensors and devices (Gartner, 2012). Reeve (2009) proposed emotions as sensory states with behavioral, cognitive, and physiological components, which are usually intense and short-term. In addition, the most prominent definition that many researchers have based their work on has a multi-component definition and perspective. In this definition, emotions are presented as multi-component and coordinated processes of the psychological subsystem, including emotional, and cognitive processes, and the motivation of peripheral facial and physiological manifestations (Damasio, 2005). In environmental psychology, Reeve (2009) considers emotion as a complex set of interactions between objective and subjective factors that are activated by hormonal-nervous systems. He believes that emotions can: 1- Increase emotional experiences such as arousal, pleasure, or lack of pleasure. 2- Produce cognitive processes such as perceptual effects, evaluations, etc. 3- They activate physiological adaptation in arousal conditions. 4- Lead to behavior that is often meaningful, goal-oriented, and adaptive.

From a philosophical point of view, Descartes identifies six "primitive" passions: "the first of all the passions," Admiration, love and hatred, desire, and joy and sadness, which the mixture of these six passions causes other feelings and sub-emotions (Leeper, 1965) and Darwin (1872) emphasized the role of emotion in social communication and believes voluntary expression of emotions, which is vital to higher species, has evolved selectively to meet the needs of social communication (Darwin, 1872). William James (1884) combined the views of Darwin and Descartes and presented a physiological theory, according to which emotion is the feeling of bodily changes that occur following the perception of reality. As well as, James (1890) confirms the connection between mental feelings and physiological states of arousal. According to him, these changes and reactions are felt as an emotional experience in the cerebral cortex area, and receiving emotional stimuli leads to hidden vascular alterations and hidden muscle reactions.

In the meantime, the difference between emotion, mood, and affect can be expressed as a subject (Kleinginna & Kleinginna, 1981), emotion is a more general concept that includes both the concepts of emotion and mood (Schwarz & Clore, 1996), emotion is created in response to a specific event and motivate specific adaptive behavior. Moods originate from ambiguous sources (Goldsmith, 1994), and are more durable (Ekman, 1973). There are different types of emotions. The theorists have presented different views regarding the types of emotion, which are stated below so that by fully understanding it, a better understanding of how architecture affects emotion can be formed.

- **Types of emotions**

Emotions have different types that can be expressed as a continuous spectrum from basic emotions to self-conscious emotions, where each emotion is different from other emotions in terms of belonging to each category. Meanwhile, shame and pride are two unpleasant self-conscious emotions (Kemeny, Gruenewald & Dickerson, 2004). Self-conscious emotions require self-awareness and self-representation, appear later than the basic emotions, facilitate the achievement of advanced social goals, do not have a unique appearance, and are part of complex cognitive phenomena (Tracy, Robins & Tangney, 2007). It can be said that since the focus of the current research is on basic emotions, the types of basic emotions and the opinions of experts in this regard will be examined in the following.

Fig. 1. Eight basic emotions related to emotion. Source: Plutchik, 1980.

There are different types of basic emotions; they range from euphoria to disgust and from fear to dysphoria (Pervin, 1996). Generally, in the 1980s, psychologist Robert Plutchik identified eight basic emotions, which he grouped into opposite pairs, including joy and sadness, anger and fear, trust and disgust, and surprise and anticipation. This classification is known as the emotion wheel chart and can be compared to the color wheel because some emotions mixed can create new complex emotions (Plutchik, 1980). Eight basic emotions related to excitement are identified in Fig. 1.

From different perspectives, emotions have been presented with different definitions. In the biological approach, they have introduced up to ten basic emotions such as anger and fear, and secondary or acquired emotions have not been considered. Rather, from the cognitive perspective, both basic and acquired emotions have been emphasized (Reeve, Deci & Ryan, 2004). In the biological approach, theorists believe that there are a few basic emotions that are the result of biology and evolution, and have identified various biological causes for different emotions. For example, Tomkins (1970) identified six emotions: joy, sadness, anger, fear, surprise, and affection (Tomkins, 1970). From the cognitive perspective, theorists believe that emotions arise in response to different meaning structures (Frijda, 1988). That is, the way people interpret the meaning of a situation determines the type of emotion they experience (Reeve, Deci & Ryan, 2004). In general, in different approaches, the basic emotions are the inherent emotions, and a set of emotions that are common in terms of physiology, mental state of feeling, expressive characteristics, etc., called non-basic emotions. From the biological perspective, the five basic emotions of anger, fear, pleasure, sadness, and hate have been identified, and from the cognitive perspective, the five basic emotions of anger, fear, sadness, joy, and love have been identified (Shaver, et al., 1987). Meanwhile, anger is the most powerful and dangerous emotion and its purpose is to destroy obstacles in the environment, and hate is to get rid of something contaminated and corrupt (Rozin, Lowery & Ebert, 1994). Sadness is the most painful emotion and results from failure experiences, joy from funny events (Shaver, Schwartz, Kirson & O'Connor, 1987), and interest (affection), the desire to explore, research, and obtain information (Reeve, Deci & Ryan, 2004). Regarding the classification of emotion, various models have been presented, which are used to measure emotion. Some of these models are complementary to the previous model and some are different from the previous model. The emotion models are investigated below.

- **Emotion models**

The standard models in the classification of types of emotions include the Circumplex model, the Vector model, Positive Affect and Negative Affect Schedule (PANAS) model, the Plutchik model, and the PAD emotional state model (Talarico & Rubin, 2009). James Russell (1980) who considers the types of emotion in a two-dimensional space inside the circle in a broad way, according to Fig. 2, where arousal and valence are marked with horizontal and vertical axes, proposed the Circumplex model and the coordinate center is neutral valence and corresponding average arousal (Russell, 1980). The vector model was presented by Bradley, Greenwald, Petry & Lang (1992) and according to Fig. 3, there is always an underlying motivational aspect as a capacity characterizing the type of emotion.

PANAS model or emotion consensual model shows that positive affect and negative affect are two separate systems (Watson & Tellegen, 1985). This model is presented in Fig. 4. This model is similar to the vector model, high-arousal states tend to be defined by their valence, and low-arousal states are more neutral in valence (Rubin & Talerico, 2009).

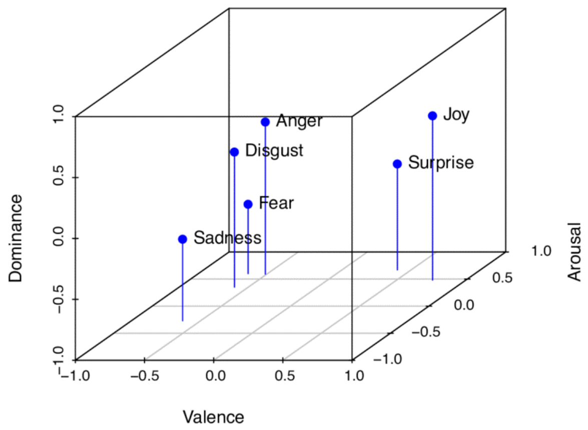

Fig. 2. Circumplex model. Source: Russell, 1980 .

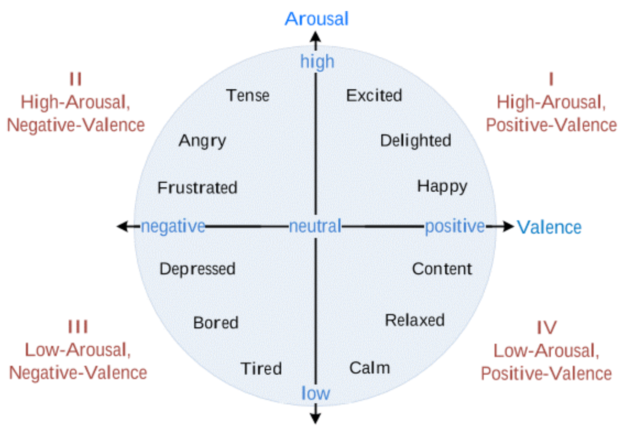

Fig. 3. Vector model. Source: Bradley, 1992.

In this model, the vertical axis shows low to high impact and the horizontal axis shows low to high negative impact, and the dimensions of valence and arousal are located in a 45-degree rotation on these axes (Watson & Tellegen, 1985). Plutchik's model, According to Fig. 5, named eight basic emotions; he grouped emotions into four opposite pairs (joy/sadness, anger/fear, expectation/surprise, affection, and kindness/hate). In this theory, which is presented with 10 basic assumptions, it is stated that emotions have arisen during evolution and human evolutionary periods have caused the emergence of new emotional levels based on fundamental emotions (Plutchik, 1982).

One of the most widely used models in connection with describing types of emotions is Russell and Mehrabian's model. The three-dimensional theory or PAD has presented three terms pleasure, arousal, and dominance, which are considered

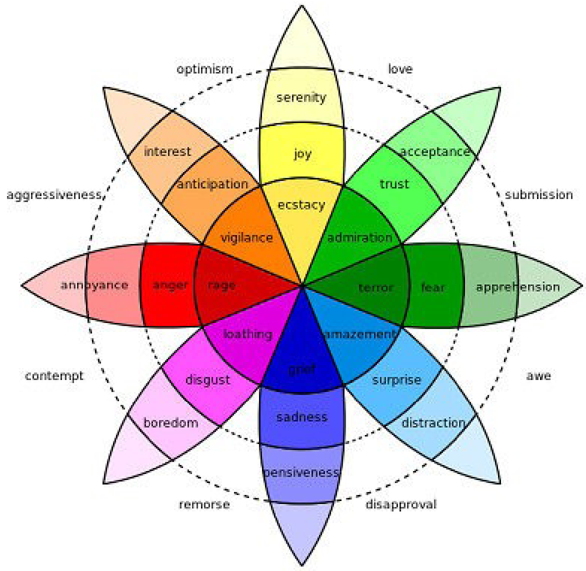

Fig. 4. Panas model or consensual model. Source: Watson and Tellegen, 1985.

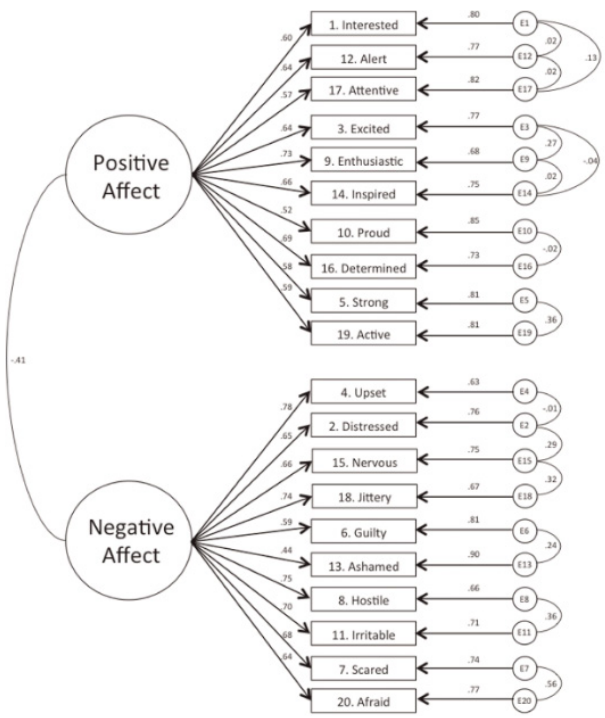

Fig. 5. Plutchik model. Source: Plutchik, 1982.

to describe and measure a certain emotional response. Pleasure-unpleasure measures the quality of emotional experience. Arousal-lack of arousal refers to the issue of physical activity and psychological-physiological changes, and the dominance dimension is defined as the sense of control or lack of control of people in a situation. The results showed that all emotions can be precisely based on these three independent and bipolar dimensions. , pleasure-unpleasure, level of arousal, and dominance can be described (Mehrabian & Russell, 1974). In Russell and Mehrabian's model, emotion is considered as an intermediary between environment and personality (influencing factor) and behavior as an output (Gifford, 2007). PAD model has been proposed for use in environmental psychology, the main idea of this model is that the environment affects people's emotional states (Mehrabian & Russell, 1974). The classification of emotion according to the three factors of the PAD model is specified in Table 1.

- **Emotion Theories**

From the beginning of attention to the emotion category, various theories have been formed over time. Psychologist William James and physiologist Carl Lange's theories about the origin and nature of emotion and is one of the first theories of emotions in modern psychology (Dewey, 1894; Barrett, 2017), proposed James-Lange theory (1884). The basic premise of the theory is that physiological arousal causes emotion in humans (Cannon, 1927). This theory proposes a physiological (physical) response in which physiological changes are primary and when the brain reacts to information received through the body's nervous system, it experiences emotion. In a way, it states that each specific emotion is related to a unique and different pattern of physiological arousal against an exciting stimulus, and what a person experiences as an emotion is a label that he puts on his/her responses (Dalgleish, 2004). In addition, George et al., (2002) in a study on the autonomic nervous system stated that this theory is "hard to disprove" . The main principles of James Long's theory are according to Fig. 6.

The main concepts of Cannon-Bard's theory (1927) are that emotional expression results from the function of hypothalamic structures, and emotional feeling results from stimulations of the dorsal thalamus (Cannon, 1927). The physiological changes and subjective feelings of emotion in response to a stimulus are separate and

Table 1. Classification of emotion according to the three factors of the PAD model. Source: Mehrabian & Russell, 1974.

Classification of emotion according to the three factors of the PAD model	
P+A+D	Arousal of Admiration, firm and strong, powerful, creative
+P+A-D	Amazed, jittery, impressed, fascinated
+P-A+D	Comfortable, leisurely, calm, satisfied
+P-A-D	sympathy, obedient, careful, sleepy, calm
-P+A+D	Opposite, hostile, cruel, disgusted, anger
-P+A-D	Confused, distressed, humiliated, in pain, upset
-P-A+D	Indifferent, selfish, disinterested, inattentive
-P-A-D	Bored, depressed, tired, lonely, sadness

Fig. 6. James-Lange theory regarding emotion. Source: adapted from James-Lange, 1884.

Fig. 7. Cannon-Bard theory of emotion. Source: Adapted from Cannon, 1972.

independent; arousal does not have to occur before the emotion. Thus, the thalamic region is attributed to a major role in this theory of emotion. The theory is therefore also referred to as the thalamic theory of emotion (Roeckelein, 2006). A key component of Cannon-Bard's theory of emotion is that when thalamic discharge occurs, physiological changes happen almost simultaneously with the experience of emotion. Physiological arousal should not precede emotional expression. And it is according to Fig. 7. This theory claims that the thalamus region is the region of the brain responsible for emotional responses to stimuli (Dalgleish, 2004). Also, he believes that the thalamus region is the coordinating center of emotional reactions, and both physiological and emotional arousal is created by nerve stimulation and simultaneously (Cannon, 1931).

Schachter-Singer's (1962) two-factor theory of emotion, states that emotion is based on two factors: physiological arousal and cognitive symptoms. According to this theory, when emotion is felt, physiological arousal occurs (Schachter and Singer, 1962). In a way, in this theory, the emotion that a person expresses is the interpretation of physiological arousal. It is according to Fig. 8.

The facial feedback hypothesis, which was documented by Lanzetta, Cartwright-Smith & Eleck, (1976), is based on the speculations of Charles Darwin and William James and states that a person's face directly affects a person's emotional experience. In general, the physiological activation of facial areas related to specific emotions has a direct effect on the creation of such emotional states, and preventing the activation of the face leads to the suppression (or general nonexistence) of emotional states (Hennenlotter et al. 2009). The main principles of face feedback theory are shown in Fig. 9. A lot of research has been done on the facial feedback hypothesis and its changes, and even the weak version of this research has been supported, so facial expressions can express emotions (Davis, Senghas, Brandt & Ochsner, 2010).

Lazarus (1991) present cognitive Appraisal theory. This theory shows that emotion is the result of evaluating information from the environment and from inside the human body, which causes

Fig. 8. Schachter-Singer theory regarding emotion. Source: Adapted from Schachter & Singer, 1962.

Fig. 9. Facial feedback. Source: Adapted from Lanzetta, Cartwright-Smith & Eleck, 1976.

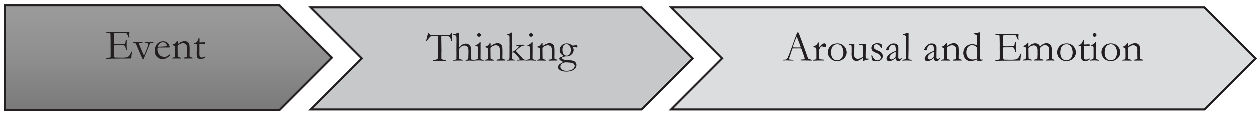

Fig. 10. Cognitive Appraisal Theory. Source: adapted from Lazarus, 1991.

different reactions in people (Scherer, Shorr & Johnstone, 2001). Based on this, the theory of cognitive evaluation is consistent with Fig. 10. The Cognitive Appraisal theory can be divided into two categories: 1-pleasure or unpleasure, 2-how much arousal is formed. This theory has more influence on behavioral environment studies (Nasar, 2011).

- **The effect of architectural space on humans**

Architecture has many effects on humans (Williams Goldhagen, 2017), the built environment affects humans on a cognitive level (as processing and evaluation of perceived information) and an emotional level (as adaptive reactions to perceived information) in a continuous manner (Ledoux, 2008). As stated, architecture has additional cognitive-emotional effects beyond its primitive features (Hietanen & Korpela, 2004). The article states that addressing the cognitive-emotional needs of users is a transcendent function in architecture (Eberhard, 2009; Veal, 2005). However, since most of the objectives of architectural design have been changed (Meyakawa, 1965) to objective and tangible issues that can be easily measured, so far this dimension has been less investigated (Changeux, 1985; Pearson, 2005).

Architecture can activate the brain and modulate genetic function (ANFA, 2005). As a result, changes in the environment have important effects on humans (Gage, 2003) and since architecture has physiological effects, changes in an environment can even improve creativity and cognitive performance (Malinin, 2014). In fact, even mild environmental stimulation affects brain development (Perry, 2002). Regarding the impact of architecture on humans, Pallasmaa says: "When I enter the space, the space enters me and transforms me" (Pallasmaa, 2018). Therefore, the importance of the built environment cannot be ignored, and future architecture must be formed by a deep study of the relationships between spaces and emotions (Debord, 2003). As well as, design experts and researchers state that the places we live in, whether urban landscapes, buildings, or natural environments, directly affect human emotions and consequently human health (Altman & Wohlwill, 1976).

Due to the importance of the topic, so far research has been conducted on the effect of interior and especially residential space on mental health, and they have shown that the type of residential interior design has an impact on people's health (Ranson, 1991; Ormandy, 2009; Thomson, 2005). Various parameters are effective in the design of the interior space, and factors such as light, color, form, materials, furniture, etc, are important requirements in this area (Coles & House, 2007). Researches in the field of mental health and residential interior space include interior space form (Banaei, Yazdanfar Hatami & Gramann, 2017), indoor air quality (Bluyssen, 2010, types of materials (Ranson, 1991), brightness and daylight (Boubekri, 2008), domestic accidents (Ormandy, 2009), neighborhood (Wandersman & Nation, 1998), humidity on public health (Ranson, 1991), the effect of indoor noise on health (Evans, 2003), Interior decoration and the effect of furniture on people's health (Sakuragawa, Miyazaki, Kaneko & Makita, 2005).

In some studies, the effect of interior design on health has been investigated. In a study, two living rooms with the same dimensions but different designs using wood have been investigated. The results have shown that a room with simple decoration provides more physical relaxation and a room with a wood design creates more active and exciting moods (Tsunetsugu, Miyazaki & Sato, 2005). In relation to the effect of indoor light on health, studies have also been conducted and the results have proven that lights with low color temperatures reduce the alpha intensity and it is recommended to use such colors in bedrooms (Noguchi & Sakaguchi, 1999). In another research, the physiological effects of indoor space have been investigated. In this study, color and design have been studied in the interior design of two real rooms. Research results have shown that the level of arousal is higher in a room with various colors (Kuller, 1986). As well as, the degree of creating arousal in interior spaces with different colors has been studied and it has been determined that the intensity of the alpha signal under the influence of red color is lower than blue (Küller, Mikellides & Janssens, 2009).

However, so far, few studies have been conducted on the effect of interior space on emotion as an effective parameter of mental health. In addition, some studies conducted in the past have used qualitative methods. Nevertheless, today, with the rapid progress of science and technology, researchers are now able to clarify the neuro-physiological impact related to emotions using medical techniques (Mavros, Austwick & Smith, 2016; Roe, Aspinall, Mavros & Coyne, 2013). One of the emerging fields that have been influential in the field of emotion measurement is neuroscience. Researchers in this field use devices such as electroencephalogram (EEG) to measure electrical activity and functional near-infrared spectroscopy (fNIRS) to measure the production of oxygen-deoxyhemoglobin cortex as a link to neural activity, or functional magnetic resonance imaging (fMRI), or others to achieve emotions affected by the environment by analyzing brain activities (Tsunetsugu, Miyazaki & Sato, 2005). Neuroscience is a modern and interdisciplinary science that has taken an effective step in promoting healthy architecture using new tools. Therefore, in the following, a definition of neuroscience is presented and how it is connected with architecture is explained.

- **Neuroscience**

Neuroscience is the science that studies the brain and the nervous system (Kandel, 2013), and since the human brain is physiologically very similar, neuroscience provides insights into the functioning of the nervous system in general (Grabenhorst & Rolls, 2011; Kircher & David, 2003). Neuroscience has various specialized fields (Breedlove & Watson, 2019), which has caused it to focus more on other fields such as cognitive neuroscience, behavioral neuroscience, neuroscience and Neurophysiological neuroscience, and sensory neuroscience (Solms & Turnbull, 2002). It also studies specifically in relation to architectural space (Clément & Reschke, 2010). Considering the influence of neuroscience in architecture (ANFA, 2005), this emerging discipline can quantify the effects of architecture on humans, improve architectural designs and add quality to the user's life and improve the health of users (Eberhard, 2009; Edelstein, 2006).

In traditional approaches, studies had limitations in instruments and appraisal (Bateson & Hui, 1992). For example, the use of photos and videos as instruments stimulate only a few interactions with reality (Ijsselsteijn, de Ridder, Freeman & Avons, 2000). Also, appraisals involving self-reports are prone to bias because they consider only the conscious aspects of human responses (Schwarz & Strack, 1999). This issue becomes important because most emotional processes occur at the unconscious level (Zaltman, 2003). However, neuroscience has made new paths possible for researchers using neuroimaging techniques. Accordingly, researchers record brain responses non-invasively (Dirican & Göktürk, 2011; Ray et al., 2003), and have been able to observe the responses of healthy subjects under controlled conditions (Fairhall & Ishai, 2008; Ishai, Fairhall & Pepperell, 2007). Various instruments are used to record changes in the Central nervous system (CNS), Autonomic nervous system (ANS), and Somatic nervous system (SNS) (Bagozzi, 1991). The CNS consists of the brain and the spinal cord, and common instruments for its study include functional magnetic resonance imaging (fMRI), Electroencephalography (EEG), and Magnetoencephalography (MEG). fMRI measures neural activity indirectly by detecting changes in magnetic properties associated with blood flow (Soares et al., 2016). EEG measures electrical field fluctuations caused by ionic currents caused by neural activity in the brain, mainly cortical areas because they are the most superficial (Cohen, 2017). MEG measures the magnetic fields created by the ion current. ANS, which is part of the peripheral nervous system, controls involuntary actions (Boto et al., 2018). Also, the SNS is a part of the peripheral nervous system that is associated with voluntary movement, each of which has different tools that are beyond the scope of this article. In addition to measuring instruments, simulating the built environment to conduct experiments and studies is an important problem and challenge in this field, and today's new technologies have overcome these limitations. As an example, virtual reality (VR) can often be simulated to create stimuli in a realistic, immersive, and interactive manner (Rheingold, 1991) in vitro and under controllable conditions (Vince, 2004). Regarding the assessment limitation, neuroscience and related technologies allow researchers to record and interpret human behavioral, physiological, and neural responses (Winkielman, Berntson & Cacioppo, 2001). It has a high level of objectivity (Poels & Dewitte, 2006) and continuous monitoring is one of the advantages of this new approach (Reinerman-Jones, Cosenzo & Nicholson , 2010).

Neuroscience researchers have long explored the concept of environmental enrichment (EE). In EE experiments, animals have been placed in a residential area that has created an opportunity to increase sensory, cognitive, motor, and social stimulation. In the results, it has been determined that the EE condition for animals has led to behavioral, cellular, and molecular changes, as well as disease improvement in some neurological conditions, compared to the conditions of the neutral built environment (Nithianantharajah & Hannan, 2006; Van Praag, Kempermann & Gage, 2000). This is because enriched environments induce higher levels of brain activation that lead to molecular changes in neuronal function and neuroplasticity (Fox, Merali & Harrison, 2006). Despite the positive effects of these tests, the application of EE in human models has many complications and is therefore less developed (Clemenson, Deng & Gage, 2015; McDonald, Hayward, Rosbergen, Jeffers & Corbett, 2018).

This emerging knowledge has made the fields of research on how architectural space influences humans in other fields to be provided. Neuroscience, a knowledge focusing on the brain and new instruments for measuring brain activities, has expanded the field for studies in the new paradigm of neuroarchitecture (Dazkir & Read, 2012; Dinis, Duarte, Noriega, Teixeira, Vilar & Rebelo, 2013; Küller, Ballal, Laike, Mikellides & Tonello, 2006; Roessler, 2012). Neuroarchitecture, which has filled the research gap of environmental psychology, architecture, and neuroscience, as a new paradigm, will influence the future of architecture.

- **Neuroarchitecture**

Looking at the past, some developments

influenced by Gestalt psychology founded the use of neuroscience in architecture (Jelić, 2015). The works of von Hayek (von Hayek, 1952) and Arnheim's research (Arnheim, 2004) in the field of psychology of art and understanding images are examples of this field. Beyond Gestalt (Hebb, 1949) took steps towards the function of neuroscience in architecture by developing a theory about how the brain creates complex psychological phenomena. Neutra created one of the first contemporary formulas for combining neuroscience knowledge with architecture (Neutra, 1954). Later authors coined the term "Neurophenomenology" and tried to reconcile the scientific approach with experience (Vijayan & Embi, 2019). In the same way, since neuroscience, compared to the basic methods, had significant advantages for measurement, it received more attention and progress (Ulrich, 1981).

The initial ideas for the connection between neuroscience and architecture were proposed in the 1950s by a life science researcher who was struggling to solve a problem. After changing his environment and building, he noticed their impact on his problem-solving process and became interested in the impact of architecture on people's health and efficiency. After that, Jonas Salk commissioned Louis Kahn to design the Salk Institute and asked him to pay attention to the effects of the environment on humans in his design (Sternberg, 2010). In 2003, "The Academy of Neuroscience for Architecture" was established in San Diego and has prepared the way for activities in this field by organizing seminars and workshops (ANFA, 2003).

The emerging interdisciplinary field of neuroarchitecture aims to develop conceptual paradigms and empirical frameworks based on the interaction between the brain, body, and built space (Chiamulera et al., 2017). Determining whether a built environment affects our well-being is an important concern, especially when we consider the interaction of the human brain with architectural settings. Neuroscience studies can contribute to a set of knowledge that explains why buildings and places affect the people who use them (Eberhard, 2009). Some researchers describe neuroarchitecture as a field in which architects collaborate with neuroscientists to scientifically investigate the relationship between people and their environment (Ezzat Ahmed and Kamel, 2021). In general, the main goal of neuroarchitecture is to study the impact of the built environment on the nervous system, which is a manifestation of human perception and an indicator of psychological well-being (Bluyssen, 2010; Pykett, 2015). By understanding how the brain perceives its environment, neuroscience can improve the design process, design strategies, and regulations that will ultimately improve human health and well-being in the future (Eberhard, 2009; Dougherty & Arbib, 2013; Azzazy, Ghaffarianhoseini, Naismith & Doborjeh, 2021).

There are two fields of study, the design process and the experience of architectural space in neuroarchitectural studies (Arbib, 2015). In connection with the design processes, it examines proposals related to how to integrate the knowledge obtained from the neuroscience function in architecture, and the investigated aspects (Banasiak, 2012; Manganelli, Green, Brooks, Mocko, Walker & Healy, 2012) in the experience of architectural space are focused on components such as light, sound, vegetation, and the daily activities orientation in the space (Hoffman, 2012). In line with these studies, they have proven the impact of light on human health (Ellis, Gonzalez & McEachron, 2013) and the improvement of users' experience of space due to the presence of appropriate light (Edelstein, 2009). In addition, these studies have proven that noise and lack of vegetation will cause stress (Glaser & Kiecolt-Glaser; Ulrich, 1979), which has a negative effect on longevity (Glaser & Kiecolt-Glaser, 2005), or they have shown the positive effect of landscape on the recovery of patients (Ulrich, 1984). In addition, environmental stimulation caused by classroom design has been investigated, which can improve students' performance (Al-Ayash, Kane, Smith & Green-Armytage, 2015). Also, according to the concept of a healing environment (Stichler, 2001), various studies have been conducted on the therapeutic benefits of the environment (Pinter-Wollman, Jeli´c & Wells, 2018). The results of neuroarchitecture studies show that the neuroscience function in architecture as an emerging field still has room for further improvement. It has also improved the quality of studies related to the impact of architectural space on human emotions. By providing new study tools and methods to investigate emotion, neuroarchitecture has provided researchers with a little data that have high measurement validity. In the following, some studies in this field have been introduced and reviewed.

- **The effect of architectural space on human emotion in neuroarchitectural studies**

The subject of the effect of architectural space on emotion has been given attention in recent years. The research results indicate that the built environment has an effect on human emotional reactions and shows how these effects occur, and the results of these studies based on neuroscience instruments promote architectural designs that have a significant impact on people's mental health (Roe, Aspinall, Mavros & Coyne, 2013). As well as, neuroscience has been widely used in studying the cognitive-emotional dimension of architecture (Linaraki & Voradaki, 2012).

Some studies of emotion based on neuroscience have been in the field of architecture and some in the field of urban planning. Roe, Aspinall, Mavros & Coyne, (2013) using a mobile EEG device and an emotive program, investigated people's emotions towards an urban environment with a street with shops, an urban landscape, and a crowded commercial street in terms of different emotions formed in people (Roe, et al., 2013). Vartanian et al. (2013) measured the beauty and its impact on decision-making by showing images from the external environment of architecture (Vartanian et al., 2013). Carmona (2014) studied the urban environment using smartphones to record people's emotions toward the environment and measure them by EEG (Carmona, 2014). In addition to the mentioned cases, other research has been conducted about the impact of the built environment on human emotions, in which different dimensions of emotion such as fear, sadness, joy, arousal, and disgust, as well as emotion and the process of emotion, have been investigated that is presented in Table 2.

Neuroarchitectural researches related to emotion generally use visual stimuli. As it is known in the research, the most widely used tools to measure emotion are fMRI and EEG. EEG is one of the most advanced techniques and the most widely used tool, which measures the fluctuations of electrical signals throughout the brain using sensitive electrodes placed on the human scalp. Electrical signals are instantly collected from multiple electrode sites, resulting in the real-time mapping of brain activity (Nidal & Malik, 2014). In this method, caps with electrodes are used, so the person can move during the test and it is the best option for conducting architectural tests (Danesh Sani, Safania & Poursoltani, 2017). Following that, fMRI is the most widely used advanced device that produces images with low thicknesses and different sections of the body (Jalali Kondori, Rahimian, Asadi & Tahsini, 2014). But due to the lack of movement of the participant in the experiment, it has limitations.

Using this tool, researchers report different areas of the brain that are activated by visual stimuli. For example, in the research, that examines the emotion process (Jalali Kondori, Rahimian, Asadi & Tahsini, 2014), the medial part of the anterior lip of the amygdala was activated. When emotion is expressed in the form of fear, the amygdala is activated, and when sadness, the cingulate cycloplegia is activated (Phan, Wager, Taylor & Liberzon, 2004), and when joy is expressed as one

Table 2. Neuroarchitectural studies regarding the effect of architectural space on emotion. Source: Authors.

Architectural Context	author	Year	Title	Monitoring technology
Emotion induction by visual stimuli	Davidson	1992	Anterior cerebral asymmetry and the nature of emotion	EEG
	Lang et al.	1998	Emotional arousal and activation of the visual cortex: an fMRI analysis. Psychophysiology	fMRI
	Cuthbert, Schupp, Bradley, Birbaumer & Lang	2000	Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report	EEG
	Phan, Wager, Taylor & Liberzon	2002	Functional Neuroimaging Studies of Human Emotions	fMRI
	Aftanas, Reva, Varlamov, Pavlov & Makhnev	2004	Analysis of Evoked EEG Synchronization and Desynchronization in Conditions of Emotional Activation in Humans: Temporal and Topographic Characteristics	EEG
	Sergerie, Chochol & Armony	2008	The role of the amygdala in emotional processing: A quantitative meta-analysis of functional neuroimaging studies	fMRI
	Bekkedal, Rossi & Panksepp	2011	Human brain EEG indices of emotions: Delineating responses to affective vocalizations by measuring frontal theta event-related synchronization	EEG
Emotion process	Sergerie, Chochol & Armony	2008	The role of the amygdala in emotional processing: A quantitative meta-analysis of functional neuroimaging studies	fMRI
	Teplan	2002	Fundamentals of EEG measurement	EEG
Fear/discomfort	Phan, Wager, Taylor & Liberzon	2002	Functional Neuroimaging Studies of Human Emotions	fMRI
Happiness	Aftanas, Varlamov, Pavlov, Makhnev & Rev	2001	Affective picture processing: event-related synchronization within individually defined human theta band is modulated by valence dimension	EEG
	Olofsson	2008	Affective picture processing: An integrative review of ERP findings	EEG
	Morris, Klahr, Shen, Villegas, Wright & Liu	2009	Mapping a multidimensional emotion in response to television commercials	fMRI
	Duerden, Arsalidou & Taylor	2013	Lateralization of affective processing in the insula	fMRI
Arousal	Keil, Müller, Gruber, Wienbruch, Stolarova & Elbert	2001	Effects of emotional arousal in the cerebral hemispheres: a study of oscillatory brain activity and event-related potentials	EEG
	Aftanas, Varlamov, Pavlov, Makhnev & Reva	2002	Time-dependent cortical asymmetries induced by emotional arousal: EEG analysis of event-related synchronization and desynchronization in individually defined frequency bands	EEG
Disgust	Murphy, Nimmo-Smith & Lawrence	2003	Functional neuroanatomy of emotions: A meta-analysis	fMRI
	Fusar-Poli et al.	2009	Functional atlas of emotional faces processing: a voxel-based meta-analysis of 105 functional magnetic resonance imaging studies	fMRI

of the dimensions of fear, the anterior cingulate and the posterior middle cingulate of the insula are activated (Morris, Klahr, Shen, Villegas, Wright & Liu, 2009; Aftanas, Varlamov, Pavlov, Makhnev & Reva, 2001; Olofsson, Nordin, Sequeira & Polich, 2008, 2008). When the other dimension of emotion, arousal, occurs, the right parietal sinus fold and the right anterior sinus fold (Aftanas, Varlamov, Pavlov, Makhnev & Reva, 2002; Keil, Müller, Gruber, Wienbruch, Stolarova & Elbert, 2001), and t»e insula is activated when disgust occurs (Fusar-Poli et al., 2009; Murphy, Nimmo-Smith & Lawrence, 2003). However, since the present study focuses on the research of the impact of the physical components of the interior space on architecture, so the interpretation of the results of the stated research is limited to this amount.

Studies and surveys (research method process)

The studies that have been conducted in the field of the effect of interior space on emotion using neuroarchitecture are divided into two categories: experimental and theoretical studies. They have also investigated the methods that are currently used to measure emotion. In this regard, a systematic review research method has been used.
In a systematic review, a more objective critical review can be performed carefully, systematically, and planned to identify all relevant studies (Egger, 2001). In addition, systematic reviews identify inconsistencies between existing research evidence (Cook and Mulrow, 1997). The main advantage of systematic reviews is that the "weight of the data" precludes the application of personal opinion and author bias (Hall, 2003), and summarizes the results of several original studies using strategies with minimal error (Mulrow, 1987; Cook, Mulrow & Haynes, 1997). A systematic review has criteria in its protocol that include the following Fig. 11 (Higgins and Green, 2008):

Inclusion Criteria

To define the inclusion criteria, several components have been specified to make the research path more precise. The components include search terms, variables used in studies, measuring instruments, and the publication date of a paper. In addition to the defined criteria, the studies must have focused on demography, and the studies that were conducted on animals were excluded from the present review.
Terms: In this review, the difference between the words affection, mood, and emotion is given special attention. These three words have separate and different definitions in neuroscience and psychology, and since the current review focuses on emotion, studies including two other words (affection and mood) are excluded from the review process. Keywords include emotion, architecture, built environment, interior space, and specialized keywords about human responses to the environment.
Measurement variables: The search was limited to reviewing physiological variables related to "architectural interior space" or "built environment interior space". In this process, the studies that dealt with the impact of social, cultural, and behavioral factors and clinical studies have been excluded. Studies must include some form of virtual environment (VE) such as VR, CAVE, AR, or XR as a controlled study environment, or be tested in physical spaces or other multisensory media

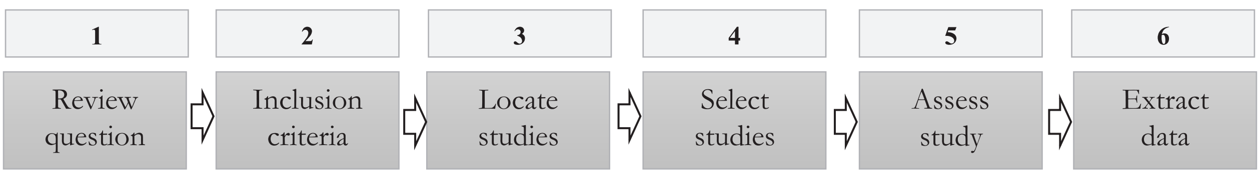

Fig. 11. Systematic review research process. Source: Adapted from Higgins & Green, 2008.

(images, videos, etc.), and studies that investigated the emotion using two-dimensional images, have been excluded from the review process.

Measuring instruments: In experimental studies of emotion investigation, two methods of objective and subjective measurement can be measured. Objective measurements of physiological responses as definitive data of emotion make the impact of architecture on humans completely clear, and subjective measurements are cognitive and self-reporting methods. In objective measurements of studies, neuroscience tools such as electroencephalogram (EEG), electrocardiogram (ECG), functional magnetic resonance imaging (fMRI), galvanic skin response (GSR) as skin resonance (SRC), measurement of changes in blood oxygenation(fNIRS) should be used and also a combination of techniques showing ANS/CNS response have been investigated. The subjective measuring instrument of emotion should also include questionnaires, surveys, self-assessment Manikin (SAM), Likert scales, verbal responses, or other items as a type of subjective self-assessment response.

Publication date: Due to the nascent nature of this research field, as well as the rapid development of technology, the search was limited to studies published between January 1, 2010, and January 1, 2020. In addition, according to the review of studies before 2010 based on Table 2, the interior space has been investigated less and its features do not meet the inclusion criteria for the current review. To extract the relevant data, the following steps were taken.

Searching and Identifying Studies

First, two electronic databases (ProQuest and Scopus) were selected as valid directories for the publication of experimental studies. Possibilities for advanced search, and modifying inclusion and exclusion criteria, helped the researchers identify the sources. Then, three Elsevier databases including EMBASE, ScienceDirect, and Scopus were used for identification. Searches were reviewed with a set of keywords in the title, abstract, keywords, questions, and hypotheses. In addition, systematic review databases; MEDLINE; PsycINFO, and Web of Science were also investigated. In addition, several articles were investigated as a manual search by checking the sources of the articles that were eligible. Google Scholar and Researchgate websites were also used to manually check the reference list of the selected articles, and using the tools available on these two websites, the articles that cited the selected articles were reviewed. It was ensured that relevant material not identified by electronic databases was included in the present review.

- **Selecting studies**

The search limits of articles were set in three groups. Three groups related to search terms were defined as follows: 1) Keywords related to experiments, stimuli, and design variables useful for finding studies related to architecture and the built environment; 2)Terms related to “methods” to study human emotional and neurophysiological responses to those stimuli and 3) keywords related to scientific terms for human response to external stimuli and different methods of revealing human conscious and unconscious processes. In each group, the “OR” function has been used to expand the search result. Among groups, the “AND” function was used to limit the number of search results and ensure that each search result provided at least one keyword.

- **Assessing study quality**

In this review, to check the quality of the work, two reviewers have independently studied the extracted sources and the reasons for accepting and rejecting them have been presented. Since there were no disagreements between reviewers, the agreement between two reviewers was also determined using Cohen’s kappa coefficient (K) test and was finally approved by the reviewer, and finally, all articles were approved by the authors and entered the review.

- **Extracting the data**

Initially, 208 results (170 from ProQuest; 38 from Scopus) were identified based on the specified search terms. After some iterations, the keyword group consisting of terms to be excluded was applied to the database and 65 studies were obtained. Meanwhile, some studies were excluded.

Excluded studies included those that were out of the research criteria. Some studies investigated the relationship between emotion and placement in urban spaces (Chen et al., 2018; Ojha et al., 2019). Some other studies have investigated the impact of outdoor built environments on emotion (Kirk, Skov, Christensen & Nygaard, 2009; Pati, O'Boyle, Hou, Nanda & Ghamari, 2016). Other studies had ambiguities in the selection of participants and did not apply some of their mentioned criteria, for example, the participants were selected from the study group of the same university (Radwan & Ergan, 2017; Sharma, Kaushal, Chandra, Singh, Mittal & Dutt, 2017) or they did not state how to control the participants and the study environment (Elbaiuomy, Hegazy & Sheta, 2018; Zhang et al., 2010). In addition, some studies did not use modern tools of neuroscience and only used questionnaires and surveys, which will cause errors due to the lack of objective information in the results of the study (Rodríguez, Rey & Alcañiz, 2011). In general, the current review process and its criteria are presented in Fig. 12.

- **Final results**

The studies that were excluded after the review had a high practical value and had important study bases, but they did not meet the inclusion criteria. Studies on the effect of indoor space on humans are extensive, but studies have investigated various components such as stress, attention, emphasis, the experience of space, and routing. Therefore, due to the value of the studies, they are summarized in Table 3. Then, the final results were reviewed and analyzed.

After displaying the titles, abstracts, and literature review of the manual search, 7 final studies were identified and agreed upon by the authors. These studies were subjected to a full-text screening systematic review, whereby the main variables in each study were grouped to identify similar trends. Also, among these studies, there were several studies by the same author that were published in two articles, which were considered as one article (Vartanian et al., 2015; Vartanian et al., 2013; Vecchiato et, Jelic, Tieri, Maglione, Matteis & Babiloni, 2015a; Vecchiato, Tieri, Jelic, De Matteis, Maglione & Babiloni, 2015b). Table 4 presents the final articles.

Findings

Based on the final results of the review, 7 articles had all the defined research criteria. Each of the articles on the impact of one of the physical components of the interior space of architecture on emotion has had studying, which is presented in Fig. 13.

- **Form**

Among the final articles of this review, three articles have studied the effect of the form and geometry of the interior space of architecture (Banaei, et al. 2017; Vartanian et al., 2013; Shemesh, et al., 2017). Banaei, Yazdanfar, Hatami & Gramann, (2017) have studied the form of the interior living room space with the aim of investigating the neurophysiological correlation of different interior forms on the emotions of the perceivers and the accompanying brain activities.

To fully understand the form of the interior space, after extracting clusters of form features through the images of the interior space, they have modeled the room models in three dimensions. A mobile brain/body imaging (MoBI) approach and an electroencephalogram (EEG) device have been used to record the participants' brain activities during spatial perception while the participants were moving in the modeled space. This study has provided a new opportunity to use EEG and mobile VR in architectural studies to investigate the human brain in participants who actively explore and experience architectural spaces in real life (Banaei, et al., 2017).

The results of this study have shown a strong effect of curved geometries on activity in the anterior cingulate cortex (ACC). Theta band activity in ACC

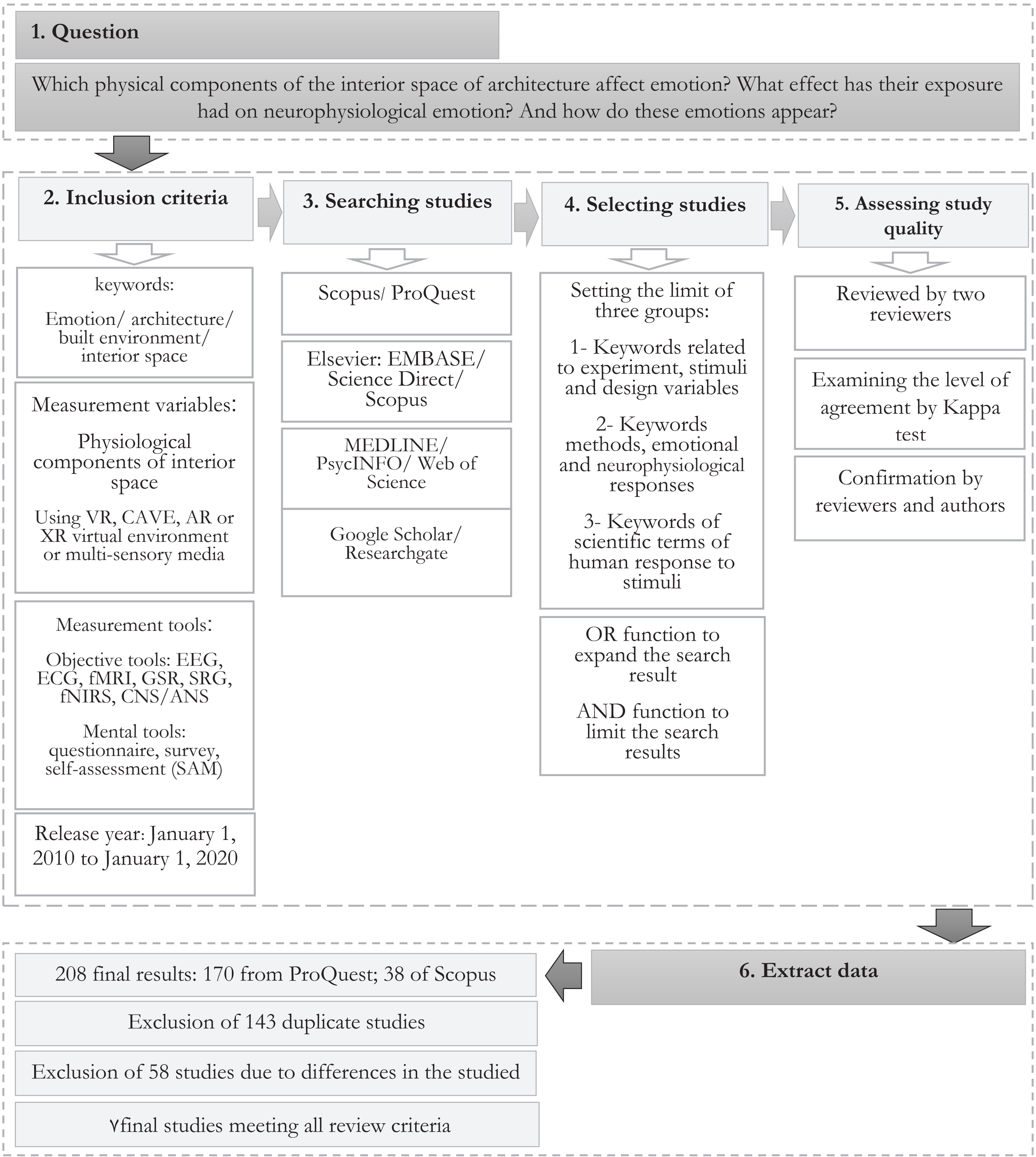

Fig. 12. Systematic review process. Source: Authors.

is related to a variety of specific features (rs(14)= 0.525, p= 0.037) and geometry (rs(14)= 0.579, p= 0.019),which provides evidence for the role of this structure in the processing of architectural features. Beyond their emotional impact, the posterior cingulate cortex and the occipital lobe were involved in the perception of different perspectives of the room during the walking through the rooms, indicating that curved spaces reported more pleasure, and the smaller the curvature of the space, the more pleasure and pleasantness has been lower. Vartanian et al. (2013) sought to investigate how interior space changes affect aesthetic judgments and decision-making. In order to

Table 3. Studies on the effect of indoor space on experience, attention, routing, aesthetics, and stress reduction. Source: Authors.

Architectural Context	Architectural space	Author(s),Year	Title	Monitoring technology
Human experience	Office	Bacevice & Duco (2022)	Use of biometric data and EEG to assess the architectural quality of two office sp aces: a pilot experiment	EEG, heart rate monitor, ECG
	health center	Higuera-Trujillo, et al. (2020)	Multisensory stress reduction: a neuro-architecture study of pediatric waiting rooms	EEG, b-Alert x10. EDA (Shimmer 3GSR+ device) HRV (b-Alert x10 device)
	Mosque	Vijayan & Embi (2019)	Probing phenomenological experiences through electroencephalography brainwave signals in neuroarchitecture study	EEG
Attention and emphasis	Residential building	Hu & Roberts (2020)	Built Environment Evaluation in Virtual Reality Environments—A Cognitive Neuroscience Approach	EEG
Wayfinding	Interior design	Erkan (2018)	Examining wayfinding behaviors in architectural spaces using brain imaging with electroencephalography (EEG)	EEG 1 channel, NeuroSky, MindWave
Aesthetics judgment	Residential building (Bedroom)	Murcia, et al., (2019)	Neural representation of different 3D architectural images: an EEG study	EEG
	Building Facade	Vannuci, et al. (2015)	The spatial frequencies influence the aesthetic judgment of buildings transculturally	aesthetic judgment tasks, and rankings
Reducing stress	Bedroom	Hekmatmanesh, et al. (2019)	Bedroom design orientation and sleep electroencephalography signals	EEG

Table 4. The final studies included in the review. Source: Authors.

	Author	Author	Title
1	Vartanian et al.	2013	Impact of contour on aesthetic judgments and approach-avoidance decisions in architecture
		2015	Architectural design and the brain: Effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions
2	Vecchiatoet al.	2015a	Neurophysiological correlates of embodiment and motivational factors during the perception of virtual architectural environments
	Vecchiato, et al.	2015b	Electroencephalographic correlates of sensorimotor integration and embodiment during the appreciation of virtual architectural environments
3	Shemesh, et al. & Grobman	2017	Affective response to architecture – investigating human reaction to spaces with different geometry
4	Zhang, Lian & Wu	2017	Human physiological responses to the wooden indoor environment
5	Banaei, et al.	2017	Walking through architectural spaces: The impact of interior forms on human brain dynamics
6	Djebbara, et al.	2019	Sensorimotor brain dynamics reflect architectural affordances
7	Yin, et al.	2019	Effects of biophilic interventions in an office on stress reaction and cognitive function: A randomized crossover study in virtual reality

study eight different images of the interior of the architecture, which have curved, and orthogonal forms; they were examined in two stages. In the implementation of aesthetic judgments, in addition to using fMRI, the participants were taught to answer "beautiful" or "ugly" by viewing each stimulus. In the avoidance approach, participants were instructed to respond with "inclusion" or "exclusion" after viewing each stimulus to indicate whether this was the space they wanted to enter or exit. After completing the fMRI scans, they collected "aesthetic" and "pleasure" ratings for

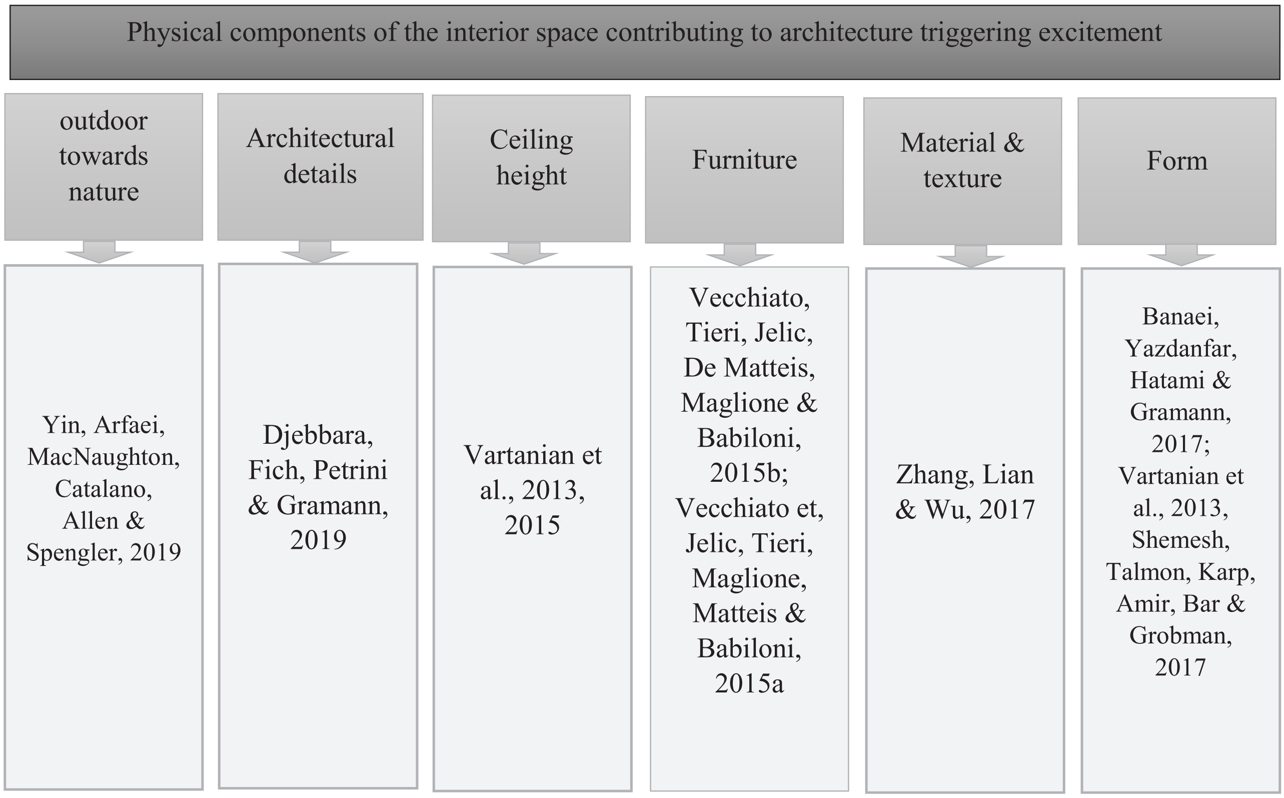

Fig. 13. Physical criteria in the final results of the systematic review. Source: Authors.

all stimuli and performed parametric analyses to further examine the relationship between brain activation and aesthetic appraisal (Vartanian et al., 2013).

The results of the research indicate that judging about aesthetics of curved interior spaces exclusively activates the ACC, and this indicates that the pleasure rating was higher in these conditions than in interior spaces. Complementing this finding, agreeableness the dimension of affective circle valence accounted for approximately 60% of the variance in aesthetic ratings. In contrast, contour does not influence avoidance approach decisions, although curved spaces activate the visual cortex. The results show that the established effect of contour on aesthetic preference can be extended to architecture. Furthermore, our combination of behavioral and neural evidence emphasizes the role of emotions in our preference for curved objects in this domain.

Shemesh, Talmon, Karp, Amir, Bar & Grobman (2017) have conducted a multifaceted study to achieve a better understanding between three-dimensional space geometry and human emotion. This study has created a framework and method for experimental investigation and measurement of human reaction to different types of architectural space geometries. This study includes two stages where the audience experiences four spaces with different geometries. Meanwhile, human reactions have been investigated by two quantitative and qualitative methods, which included a questionnaire in the first experiment and advanced sensors and data analysis in the second experiment. VR and EEG recorded the experiments. This research has pointed to gaps in human understanding of the relationship between emotion and architectural space“in general and in particular” the geometry of architectural space (Shemesh, Talmon, Karp, Amir, Bar & Grobman, 2017).

The results of this study showed that participants without design expertise tend to prefer curved spaces and show great interest in these spaces. Participants with a design background tended to prefer spaces with sharp angles. The preliminary results from the second phase of the research show the ability of the unconscious brain of the participants to understand symmetrical spaces differently from asymmetrical spaces. No difference was detected between positive and negative responses in the current setting, and there was no correlation between how subjects responded to the space geometry in the first phase and direct measurements.

- **Furniture**

Vecchiato, et al. (2015b), Vecchiato et al. (2015a) investigated the arrangement and type of furniture in the interior of the bedroom and its effect on emotion. In this study, three architectural spaces were shown to the audience using the immersive virtual reality environment of VEs, and EEG-recorded brain activities. Afterward, participants were asked to describe their experiences in terms of familiarity, novelty, comfort, pleasure, arousal, and presence using a rating scale of 1 to 9. The collected scores were then used to analyze EEG power spectral density (PSD) for each behavioral dimension in theta, alpha, and mo bands using time-frequency analysis and topographic statistical maps (Vecchiato, et al., 2015b; Vecchiato et, et al, 2015a).

Presence in the tested space of this study led to frontal midline theta activation, which indicates the involvement of sensory-motor integration mechanisms, and this is when they spent more time in the virtual space. Similar patterns also define the familiar and comfortable virtual space experience. In addition, pleasant virtual spaces increase theta power in visuomotor circuits and activate the alpha band in regions dedicated to spatial exploration and processing of spatial categorical relations. Finally, the lack of coordination of rhythm described the perception of pleasant and comfortable spaces, which indicated the involvement of left motor areas and embodied mechanisms for the perception of the environment. Overall, these results demonstrate the possibility of measuring the EEG correlates of architectural perception, which includes the brain circuits of sensorimotor integration, spatial navigation, and visualization. These observations can help test architectural hypotheses to design environments that meet the changing needs of humans. The result of this study shows that the perception of pleasant and modern interior spaces activates visual-spatial processing areas in the frontal-occipital network and indicates the involvement of motor and cognitive processes during the evaluation of spaces and will stimulate positive emotions.

- **Material & texture**

Zhang, Lian & Wu (2017) stated the purpose of the study was to investigate distinct physiological responses to wooden and non-wooden indoor environments. In this study, different types of indicators in interior design have been investigated from the perspective of three different types of space that have wooden texture or steel and concrete or white plaster, which has caused significant differences in the physiology of the participants. By investigating Electrocardiography, blood pressure, Electro-dermal activities, Oxyhemoglobin saturation, and Near distance vision were recorded when exposed to different conditions in the rooms, and these physiological responses were evaluated in 90 minutes (Zhang et al., 2017).

The results showed that there was less tension and fatigue in the wooden rooms than in the non-wooden rooms where the participants were doing their work. In addition, this study showed that environments with wood materials were beneficial for the autonomic nervous system; respiratory system, and visual system. In addition, wooden rooms have a valuable role in physiological settings and ease of performance, especially after a consecutive work period. These results provide an empirical basis to support that a wooden environment is more beneficial for indoor occupants than a non-wooden indoor environment. In general, this study showed that the presence of materials such as wood, without the conscious understanding of the audience, changes his emotions with the ANS response and reduces fatigue.

- **Ceiling height**

Vatanian et al. (2015) have investigated the effects of ceiling height and space as a visually permeable components on aesthetic judgments and decisions in architectural design. During the study, functional magnetic resonance imaging (fMRI) was used to investigate the effects of height on humans. In this research, the results have been evaluated through two ways of analyzing behavioral effects (choice, avoidance, and decisions) and neurological effects (by fMRI) (Vartanian et al., 2015).

The results of this research show that rooms with higher ceilings are evaluated as beautiful spaces, and short and confined ceilings induce the activation of the anterior medial cortex (aMCC) in the audience to decide to leave. In particular, our aesthetic preference for rooms with higher ceilings appears to be associated with activation in parietal and frontal structures located in the dorsal stream that support visual-spatial exploration and attention, suggesting that aspects of spatial cognition may be calculating the aesthetic priority for these cases will help. There is also experimental evidence that the involvement of the temporal lobes during aesthetic judgments regarding open spaces may be related to their role in the temporal dynamics of vision or the representation of abstract motion, although these possibilities await direct testing. Finally, not only did enclosures elicit more avoidance decisions, but they also activated the aMCC (a region that receives direct input from the amygdala and is involved in fear processing). These observations raise the possibility that a reduction in perceived visual and motor permeability may trigger a negative emotional response and decision to exit the space.

- **Architectural details**

Djebbara, Fich, Petrini & Gramann (2019) measured the physiological reactions of the participants using the virtual environment of two connected spaces designed between two rooms in 3 different states: difficult to pass, passable, and easily passable between 20 and 150 cm in the considered, studied. After completing the experiment, the participants were asked to complete the Self-Assessment Manikin (SAM). Because of studying the reactions of the participants by analyzing the EEG data and the SAM test, the audience's reactions to the three experiments have been investigated. The present study provides strong evidence for imperative processing at early perceptual stages and links action and perception in a similar way to active inference (Djebbara, Fich, Petrini & Gramann, 2019).

The results of this research point to a concept of the brain that seems to deal with "how I can act," while parallel processes occur with reference to "what I perceive." Therefore, these results support the hypothesis that the perception of the environment is influenced by abilities and action itself, and thus ability and action can influence the experience of an environment. Given the importance of capabilities and action to brain dynamics, this emphasizes the general idea of functionalism as a holistic approach to the study of cognition. The research does not emphasize that architectural details are directly represented as a specific component of ERP, but they provide evidence for a perceptual-action account of cognition, which is systematically differentiated according to the definition of abilities. Moreover, the final result of placement in front of doors with medium and large widths causes arousal.

- **Access to nature**

Yin, Arfaei, MacNaughton, Catalano, Allen & Spengler (2019), evaluate the biophilia hypothesis that humans have an inherent connection with nature, in this regard; they evaluated three open, semi-enclosed and enclosed office environments. In addition, using virtual reality, the participants were placed in three designed environments and were recorded by monitoring ECG, GSR, eye tracking, heart rate, blood pressure, and skin conductance level, and performed qualitative cognitive tests to measure reaction time (Yin,et al, 2019).

The results of this study show that biophilic interventions can help reduce stress and improve creativity. Moreover, these effects are related to both types of biophilic elements and may differ based on the type of workspace (outdoor vs. indoor). This research shows that VR-simulated office spaces with access to nature reduce stress, while indoors are more arousal.

- **Comparison of studies**

Methodology of space study: Four studies have used clustering and a purposeful method in the design of their tested space, which includes: comparing the space of a simple room versus 17 different structures(Banaei, et al, 2017), the style and type of arrangement of bedroom furniture against an empty room and a modern and advanced furnished environment(Vecchiato, et al, 2015b), the effect of texture wood in the interior environment is compared to an environment made of concrete and steel and a white room(Zhang, Lian & Wu, 2017), increasing the width between the two rooms in three different modes and changing their color(Djebbara, Fich, Petrini & Gramann, 2019). The other three studies did not provide a specific method of control or methodology for the design of their study criteria, which include: Checking the geometry of square, round, sharp, and curved spaces (Shemesh, et al, 2017), comparing outdoor with high ceilings, indoor with high ceilings, outdoor with short ceilings (Vartanian et al., 2013), and access to nature outdoors versus indoors (Yin, et al, 2019). The methodology of the studies extracted from the review is presented in Table 5.

Demography: In the selection of the study population, there was no focus on age, gender, culture, or specific geographical region, and most of the studies randomly selected the demography. In the study (Zhang, Lian & Wu, 2017), the number of male and female participants was equal (Vecchiato et al, 2015a), the approximate gender equality was with one woman more than men, and other studies had an asymmetric combination of gender. No specific criterion has been announced in the way of selection and selection of the population, and it has only been mentioned that they are physically healthy and have proper vision ability. The study population of the studies is presented in Table 6.

The studied environment: The studied environment has been a real architectural space in only one article (Zhang, Lian & Wu, 2017). In two articles, the interior space of the architecture has been measured in an fMRI magnetic resonance imaging room using two-dimensional images (Vartanian et al.,2013, 2015), and the rest of the studies have investigated emotion using the VR virtual environment. In addition, IEQ variables, which

Table 5. Methodology of space study. Source: Authors.

Author	Independent variables
Vartanian et al., 2013, 2015	Enclosure and Height
Vecchiato, et ali, 2015b; Vecchiato eet al, 2015a	furnishing style in a bedroom
Shemesh, et al, 2017	Form of objects
Zhang, Lian & Wu, 2017	Materiality (wood texture)
Banaei, et al, 2017	Various architectural styles
Djebbara, Fich, Petrini & Gramann, 2019	Size of the entrance between two rooms
Yin, et al, 2019	Open space VS enclosed space

Table 6. The population studied in the articles. Source: Authors.

Authors	Population (M)	Population (F)	Study Size	Age mean
Banaei, et al, 2017	7	8	15	28.6
Vartanian et al., 2013	6	12	18	23.39
Shemesh, et al, 2017	NR	NR	42	NR
Vecchiato, et al, 2015b; Vecchiato et al, 2015a	7	5	12	26.8
Zhang, Lian & Wu, 2017	10	10	20	26
Vartanian et al., 2015	6	12	18	23.39
Djebbara, et al, 2019	11	9	20	28.1
Yin, et al, 2019	8	22	30	26.3

include lighting, humidity, temperature, etc., are factors that can influence human emotions. Seven studies that were formed in the virtual environment did not provide information about the IEQ of the environment, and only one article (Zhang et al., 2017) mentioned these factors and reported that the environment had a temperature of 22- 24 degrees Celsius, the humidity of 30-40%. The studies environment of articles is presented in Table 7.

Instruments: In choosing instruments and technologies to measure emotion, each study has a single approach and some studies have used a combination of instruments. Therefore, no comparison can be made in this regard. In general, the EEG tools used in three studies have been used, using a wet electrode or a dry electrode EMOTIV system. Another instrument has been in fMRI studies, each of which has different channels. The subjective measurement methods have included questionnaires, Profile of Mood States (POMS), (Slater-Usoh-Steed (SUS) and Sanchez-Vives and Slater and self-assessment Manikin (SAM), and the investigated criteria include experience, arousal, dominance, valence, familiarity, novelty, comfort, pleasure, and presence. Research instruments for studies is presented in Table 8.

Results

In general, the final results of the studies related to the physical components of the interior space of architecture on emotion are summarized in the form of Fig. 14.

Discussion of Findings

The limited number of the final results of the review and in general all the studies in this field indicates the emerging nature of this field of studies, which has caused limitations and challenges in the methodology, statistical population, and instrument. But the new methods of final studies also have advantages that have a great impact on future studies.

Limitation: Although all the final studies have emphasized the effect of interior architecture on emotion, each of them has used different methods and instruments to measure emotion, which has made it impossible to define a specific framework and a clear method. For this reason, they have not been able to repeat or even validate the findings in future studies. This issue indicates that this field needs more studies to be able to define a certain process for it. Another limitation of these studies is the small and limited statistical population, which is sometimes limited to a specific stratum or age, which itself limits the results and may not be expandable. In addition to the mentioned cases, the studies have various methods in the analysis of information, which require more experiments to prove the correctness of the methodologies and analysis of the results.

Advantage: Before the emergence of neuroarchitecture, most of the studies in this field were done qualitatively, and since its analysis and measurement depended largely on the researcher, which caused errors or biases in the results. But in the final studies of this review, using modern instruments of neuroscience such as fMRI and EEG, the results were quantitatively

Table 7. The studies environment of articles. Source: Authors.

Authors	Method of experience
Banaei, et al., 2017	3D virtual HTC vive chead
Vartanian et al., 2013, 2015	2D image in fMRI Signal Excite HD
Shemesh, et al., 2017	3D virtual CAVE VizTech software
Vecchiato, et al., 2015b; Vecchiato et al., 2015a	3D Virtual CAVE using 3DS Max 2011
Zhang, Lian & Wu, 2017	Physical room
Djebbara, et al., 2019	3D virtual space
Yin, et al., 2019	3D virtual CAVE VizTech software

Table 8. Research instruments for studies. Source: Authors.

Author	Objective measurement tools	Subjective measurement	Data analysis technique
Vartanian et al., 2013, 2015	fMRI	Slater-Usoh-Steed (SUS)	-
Vecchiato, et al., 2015b; Vecchiato eet al., 2015a	EEG 24- Channel	Profile of Moods Scale (POMS)	ANOVA
Shemesh, et al., 2017	EEG 64- Channel	Sanchez-Vives & Slater questionnaires	ANOVA
Zhang, et al., 2017	(ECG)/ skin resistance/ skin temperature/ blood pressure/ oxyhemoglobin saturation (SpO2)	-	G*Power
Banaei, et al., 2017	EEG 128-channel	SAM	ANOVA
Djebbara, et al., 2019	EEG 64- Channel	SAM	ANOVA
Yin, et al., 2019	EEG/ GSR/ Eye Tracker/ Pulse rate/ Blood Pressure	Questionnaires	ANOVA

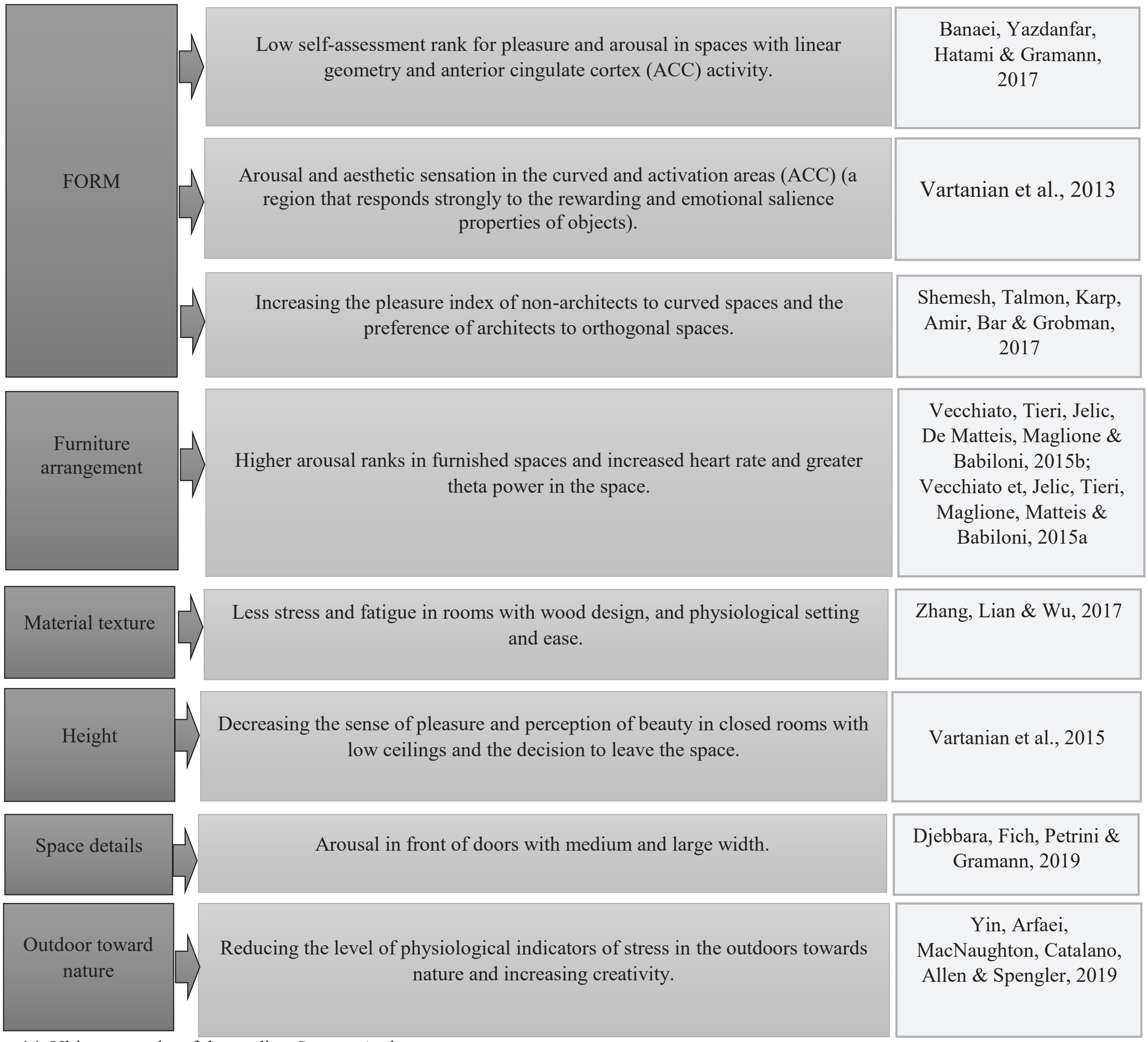

Fig. 14. Ultimate results of the studies. Source: Authors.

measured, which provided a deeper and more detailed insight into the neural structures activated during the experiment. Also, other physiological instruments such as GSR, HR, and BP have been very useful to determine the body’s response to a stimulus. The simultaneous use of these instruments and the help of self-reporting instruments such as SAM have led to a better and more understanding of brain responses to architectural space stimuli. Although these instruments provide information that the brain is responding to the stimulus, it is not enough as the only tool to detect the cause of neural activation and its origin, and they are suitable for confirming the occurrence of the reaction, but fMRI and EEG devices can record CNS activity.

Conclusion

According to the review that was done in the present research, it has been determined that due to the newness of the field of study, there is no valid and specific method to evaluate how interior design affects human emotions. This has led to the formation of a set of different techniques and approaches to conducting research. In addition, so far few studies have been conducted on the relationship between architectural interior design elements and neurophysiological responses. However, this new field of study shows that emotions are influenced by visual features in architectural interior design and can be objectively measured and lead to a wide range of neural and physiological activities.

According to the results of the review, the physical components of the form, materials, texture, furniture, ceiling height, arrangement, and architectural details, indoor and outdoor are influential in human emotions. In this way, the curved forms in the design of the interior space of the architecture increase the activity of the anterior cingulate cortex of the brain. This layer induces a feeling of pleasure and arousal with its activity and makes a person feel more relaxed in such an environment and even consider it more beautiful. The remarkable thing is that architects prefer orthogonal spaces, while non-architects preferred curved spaces. Regarding the materials and texture of the interior architecture, according to the results, it has been determined that the use of wood texture in the interior design induces less tension and fatigue in the residents and adjusts the physiological, therefore it leads to a feeling of relaxation and arousal. Furniture is a major component of interior design, and its influence cannot be easily overlooked. As mentioned, spaces with furniture increase heart rate and more theta power, emphasizing its effect on human emotions. The measure of ceiling height is also effective in human emotion, in such a way that rooms with low height and indoors induce a feeling of disgust and decision to leave in people, while a room with higher height and outdoors evokes a feeling of pleasure. Another criterion affecting emotion is a connection with nature or biophilic, which can be created in interior design by creating an outdoor towards nature.

According to the results, connecting with nature through opening reduces fatigue and increases creativity, and it can be called an important criterion for the interior design of a healthy space. Due to the new emergence of this field of study, there is a great research gap in both subjective and objective components for future researchers. For example, objective components such as color and light or mental components such as the sense of belonging and the sense of place have not been investigated. The present research has been a step in identifying experimental studies so that researchers have a source to identify methods and components in the last five years.

Reference list

- AIWH. (2018). *Mental health services in Australia, summary of mental health services in Australia*. Australian institute of health and welfare.
- Aftanas, L. I., Varlamov, A. A., Pavlov, S. V., Makhnev, V. P.& Reva, N. V. (2001). Affective picture processing: event-related synchronization within individually defined human theta band is modulated by valence dimension. *Neuroscience Letters*, 303(2), 115–118.
- Aftanas, L. I., Varlamov, A. A., Pavlov, S. V., Makhnev, V. P. & Reva, N. V. (2002). Time-dependent cortical asymmetries induced by emotional arousal: EEG analysis of event-related synchronization and desynchronization in individually defined frequency bands. *International Journal of Psychophysiology*, 44(1), 67–82.
- Aftanas, L. I., Reva, N. V., Varlamov, A. A., Pavlov, S. V. &

Makhnev, V. P. (2004). Analysis of Evoked EEG Synchronization and Desynchronization in Conditions of Emotional Activation in Humans: Temporal and Topographic Characteristics. *Neuroscience and Behavioral Physiology*, 34(8), 859–867.
- Altman, I. & Wohlwill, J. F. (1976). *Human behavior and environment: Advances in theory and research.* New York: Plenum Press.
- Al-Ayash, A., Kane, R. T., Smith, D. & Green-Armytage, P. (2015). The influence of color on student emotion, heart rate, and performance in learning environments. *Color Res.*, (42), 196–205.
- Arnheim, R. (2004). *Art and Visual Perception: A Psychology of the Creative Eye*. Berkeley: University of California.
- ANFA. (2003). *History of ANFA*. Retrieved Jul 7, 2018 from http://anfarch.org/about- 2/history/.
- ANFA. (2005A). *Mapping Memory of Space & Place. Report on the 2005 Workshop on Neuroscience & Health Care Architecture*. ANFA, Woods Hole, MA, USA.
- ANFA. (2005B). *Neuroscience & The Architecture of Spiritual Spaces*. ANFA, Columbus, OH, USA.
- Arbib, M. A. (2015). Toward a Neuroscience of the Design Process. In S. Robinson & J. Pallasmaa (Eds.), *Mind in Architecture: Neuroscience, Embodiment, and the Future of Design.* Cambridge: MIT Press.
- Azzazy, S., Ghaffarianhoseini, A., GhaffarianHoseini, A., Naismith, N. & Doborjeh, Z. (2021). A critical review on the impact of built environment on users' measured brain activity. *Archit. Sci. Rev,* (64), 319–335.
- Bacevice, P. A. & Ducao, A. (2022). Use of biometric data and EEG to assess architectural quality of two office spaces: a pilot experiment. *Intelligent Buildings International*, *14*(4), 433-454.
- Bagozzi, R. P. (1991). The role of psychophysiology in consumer research: In T. S. Robertson & H. H. Kassarjian (Eds.), *Handbook of Consumer Behavior*. Prentice-Hall, Englewood Cliffs, NJ, USA.
- Banaei, M., Yazdanfar, A., Hatami, J., & Gramann, K. (2017). Walking through architectural spaces: The impact of interior forms on human brain dynamics. *Frontiers in Human Neuroscience*, (11), 477.
- Barrett, L. F. (2017). *How Emotions are Made: The Secret Life of the Brain*. *Houghton Mifflin Harcourt*. Boston: Mariner Books.
- Bateson, J. E. & Hui, M. K. (1992). The ecological validity of photographic slides and videotapes in simulating the service setting. *Journal of Consumer Research*, *19*(2), 271-281.
- Banasiak, M. (2012). Cultivating a culture for Neuro-Architecture. *In Proceedings of the ANFA Conference—Poster Session; Academy of Neuroscience for Architecture*. La Jolla, CA, USA.
- Barker, E. (1978). Sociology. *Group Analysis*, 11(2), 173–180.
- Bekkedal, M. Y. V., Rossi, J. & Panksepp, J. (2011). Human brain EEG indices of emotions: Delineating responses to affective vocalizations by measuring frontal theta event-related synchronization. *Neuroscience & Biobehavioral Reviews*, 35(9), 1959–1970.
- Bluyssen, P. M. (2010). Towards New Methods and Ways to Create Healthy and Comfortable Buildings. *Building and Environment,* 45 (4), 808–818.
- Bradley, M. M., Greenwald, M. K., Petry, M. C. & Lang, P. J. (1992). Remembering pictures: Pleasure and arousal in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18 (2), 379–390.
- Breedlove, S. M. & Watson, N. V. (2019). *Behavioral Neuroscience*. Sunderland: Sinauer Associates.
- Boubekri, M. (2008). *Daylighting, Architecture and Health: Building Design Strategies.* Architectural Press.
- Boto, E., Holmes, N., Leggett, J., Roberts, G., Shah, V., Meyer, S. S., Duque, L., Mullinger, K. J., Tierney, T. M., Bestmann, S., Barnes, G.R., Bowetwll, R.W., Brookes, M.J., (2018). Moving magnetoencephalography towards real-world applications with a wearable system. *Nature*, (555), 657–661.
- Carmona, M. (2014). The Place-shaping Continuum: A Theory of Urban Design Process, *Journal of Urban Design* 19(1), 2-36.
- Coles, J., House, N. (2007). *The Fundamentals of Interior Architecture*. Huntly, United Kingdom: AVA Publishing.
- Cannon, W. (1927). The James-Lange Theory of Emotions: A Critical Examination and an Alternative Theory. *The American Journal of Psychology*, 39 (1/4), 106–124.
- Cannon, W. B. (1931). Again the James - Lange and the thalamic theories of emotion. *Psychological Review*, 38 (4), 281–295.
- Chen, Z., Schulz, S., Qiu, M., Yang, W., He, X., Wang, Z. & Yang, L. (2018). Assessing affective experience of in-situ environmental walk via wearable biosensors for evidence-based design. *Cognitive Systems Research*, (52), 970-977.
- Changeux, J. P. (1985). *Neuronal Man*. Princeton: Princeton University Press.
- Chiamulera, C., Ferrandi, E., Benvegnù, G., Ferraro, S., Tommasi, F., Maris, B., ... & Bosi, S. (2017). Virtual reality for neuroarchitecture: cue reactivity in built spaces. *Frontiers in psychology*, (8), 185.
- Clément, G. & Reschke, M. F. (2010). *Neuroscience in Space*. NY: Springer Science & Business Media.
- Clemenson, G. D., Deng, W. & Gage, F. H. (2015). Environmental enrichment and neurogenesis: From mice to humans. *Current Opinion in Behavioral Sciences*, (4), 56–62.
- Cohen, M. X. (2017). Where Does EEG Come from and What Does It Mean? *Trends Neurosci*, (40), 208–218.
- Cook, D. J., Mulrow, C. D. & Haynes, R. D. (1997) Systematic reviews: synthesis of best evidence for clinical decisions. *Annals of*

Internal Medicine, 126 (5), 376-80.

- Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology*, 52(2), 95–111.
- Davis, J. I., Senghas, A., Brandt, F. & Ochsner, K. N. (2010). The effects of BOTOX injections on emotional experience. *Emotion*, 10 (3), 433–440.
- Dalgleish, T. (2004). The emotional brain. *Nature Reviews Neuroscience*, 5 (7), 582–589.
- Damasio, A. (2005). *Descartes error: emotion, reason, and the human brain*, London: Penguin Books Ltd.
- Danesh Sani, K., Safania, A. M. & Poursoltani, H. (2017). Identification and Prioritization of Factors Affecting Neuromarketing in Sport Based on Analytical Hierarchy Process (AHP). *The Neuroscience Journal of Shefaye Khatam*, *5*(3), 35-43.
- Darwin, C. R. (1872). *The Expression of Emotions in Human and Animals*. London: Murray.
- Dazkir, S. S. & Read, M. A. (2012). Furniture forms and their influence on our emotional responses toward interior environments. *Environment and Behavior*, 44(5), 722–732.
- Debord, G. L. (2003). *Sociedad Del Espectáculo*. Valencia: Pre-textos.
- Davidson, R. J. (1992). Anterior cerebral asymmetry and the nature of emotion. *Brain and Cognit.* 20(1), 125-151.
- Dewey, J. (1894). The theory of emotion: I: Emotional attitudes. *Psychological Review*, 1(6), 553–569.
- Dinis, S., Duarte, E., Noriega, P., Teixeira, L., Vilar, E. & Rebelo, F. (2013*). Evaluating emotional responses to the interior design of a hospital room: A study using virtual reality. Paper presented at the design, user experience, and usability. User experience in novel technological environments*. Berlin: Heidelberg.
- Dirican, A.C. & Göktürk, M. (2011). Psychophysiological measures of human cognitive states applied in human computer interaction. *Procedia Comput. Sci*, (3), 1361–1367.
- Djebbara, Z., Fich, L. B., Petrini, L. & Gramann, K. (2019). Sensorimotor brain dynamics reflect architectural affordances. *PNAS Proceedings of the National Academy of Sciences of the United States of America*, 116(29), 14769–14778.
- Dorn, T. J. (1998). *Relationship Amongst Guilt-Proneness, Shame-Proneness and the Forgiveness of Others.* (Unpublishe MA thesis). University of Alberta, Canada.
- Dougherty, B. O. & Arbib, M. A. (2013). The evolution of neuroscience for architecture: introducing the special issue. *Intell. Build. Int*. (5), 4–9.
- Duerden, E. G., Arsalidou, M., Lee, M. & Taylor, M. J. (2013). Lateralization of affective processing in the insula. *NeuroImage*, (78), 159–175.
- Duchowski, A. (2003). *Eye tracking Methodology: Theory and Practice*. London: Springer Science & Business Media.
- Eberhard, J. P. (2009). Applying neuroscience to architecture. *Neuron*, 62(6), 753–756.
- Edelstein, E. A. (2009). Influence of architectural lighting on health. *Inf. Newsl*, (7), 1–5.
- Egger, M. (2001). *Systematic reviews in health care*. London: BMJ publishing group.
- Ekman, P. (1973). Cross-cultural studies of facial expression. In P. Ekman (Ed.), *Darwin and facial expression: A century of research in review*. New York: Academic Press.
- Elbaiuomy, E., Hegazy, I. & Sheta, S. (2018). The impact of architectural spaces' geometric forms and construction materials on the users' brainwaves and consciousness status. *International Journal of Low Carbon Technologies*, 13(1), 43–51.
- Ellis, E. V., Gonzalez, E. W. & McEachron, D. L. (2013). Chronobioengineering indoor lighting to enhance facilities for ageing and Alzheimer's disorder. *Intell. Build. Int*, (5), 48–60.
- Erkan, İ. (2018). Examining wayfinding behaviours in architectural spaces using brain imaging with electroencephalography (EEG). *Architectural Science Review*, *61*(6), 410-428.
- Evans, G. W. & McCoy, J. M. (1998). When buildings don't work: The role of architecture in human health. *Journal of Environmental Psychology*, 18(1), 85–94.
- Evans D. (2003). Hierarchy of evidence: a framework for ranking evidence evaluating healthcare interventions. *Journal of clinical nursing*, 12(1), 77–84.
- Ezzat Ahmed, D. & Kamel, S. (2021). Exploring the contribution of neuroarchitecture in learning environments design "a review". *Int. J. Archit. Eng. Urban Res*, (4), 102–119.
- Fairhall, S. L. & Ishai, A. (2008). Neural correlates of object indeterminacy in art compositions. Conscious. *Cogn*. (17), 923–932
- Ferguson, K. T., & Evans, G. W. (2018). *The built environment and mental health reference Module in earth Systems and environmental sciences*. Amsterdam: Elsevier.
- Frijda, N. H. (1988). *The laws of emotions*. American Psychologist, 43(5), 349– 358.
- Fruzzetti, A. E. & Erikson, K. R. (2010). *Mindfulness and acceptance interventions in Cognitive –behavioral therapy*. Handbook of cognitive-behavioral therapies. New York City: Guilford Press.
- Fox, C., Merali, Z. & Harrison, C. (2006). Therapeutic and protective effect of environmental enrichment against psychogenic and neurogenic stress. *Behavioural Brain Research*, 175(1), 1–8.
- Fusar-Poli, P., Placentino, A., Carletti, F., Landi, P., Allen, P., Surguladze, S. ... & Politi, P. (2009). Functional atlas of emotional faces processing: a voxel-based meta-analysis of 105 functional

magnetic resonance imaging studies. *Journal of psychiatry and neuroscience*, *34*(6), 418-432.

- Gage, F. H. (2003). *Theme Presentation*. San Diego: The Salk Institute.
- Gartner, G. (2012). *Emotional response to space as an additional concept in cartography, International Archives of the Photogrammetry*. Remote Sensing and Spatial Information Sciences, Vol. XXXIX-B4, XXII ISPRS Congress, Melbourne, Australia.
- George, M. S., Nahas, Z., Bohning, D. E., Kozel, F. A., Anderson, B., Chae, J. H. ... & Mu, C. M. D. P. (2002). Vagus nerve stimulation therapy: a research update. *Neurology*, *59*(6 suppl 4), S56-S61.
- Gifford, R. (2007). *Enviromental osychology: Principles and practice*. WA: Optimal books Colville.
- Glass, D. C. & Singer, J. E. (1972). *Urban Stress: Experiments on Noise and Social stressors*. New York: Academic Press.
- Glaser, R. & Kiecolt-Glaser, J. K. (2005). Stress-induced immune dysfunction: Implications for health. *Nat. Rev. Immunol*., (5), 243–251.
- Golman, D. (2002). *Primal Leadership: Realizing the power of Emotional Intelligence, Boston*. MA: Harward Business School Publishing.
- Grabenhorst, F. & Rolls, E. T. (2011). Value, pleasure and choice in the ventral prefrontal cortex. *Trends Cogn. Sci.,* (15), 56–67.
- Goldsmith, H. H. & Harman, C. (1994). Temperament and Attachment: Individuals and Relationships. *Current Directions in Psychological Science*, 3(2), 53–57.
- Hall, G. M. (2003). *How to write a paper*. London: BMJ publishing group.
- Hebb, D. O. (1949). *The Organisation of Behavior*. Wiley: New York.
- Hekmatmanesh, A., Banaei, M., Haghighi, K. S., & Najafi, A. (2019). Bedroom design orientation and sleep electroencephalography signals. *Acta Medica International*, *6*(1), 33.
- Hennenlotter, A., Dresel, Ch., Castrop, F., Ceballos-Baumann, A. O., Wohlschläger, A. M. & Haslinger, B. (2009). The Link between Facial Feedback and Neural Activity within Central Circuitries of Emotion—New Insights from Botulinum Toxin–Induced Denervation of Frown Muscles. *Cerebral Cortex,* 19 (3), 537–542.
- Hietanen, J. K. & Korpela, K. M. (2004). Do both negative and positive environmental scenes elicit rapid affective processing? Environ. *Behav*, (36), 558–577.
- Higgins J. P. T. & Green S. (2008). *Cochrane handbook for systematic reviews. Version 5.0.0: The Cochrane Collaboration*. Retrieved Jan 12, 2022 from www.cochrane-handbook.org
- Higuera-Trujillo J. L., Llinares Millan C., Montanana I., Avino A. & Rojas, J. C. (2020). Multisensory stress reduction: a neuro-architecture study of paediatric waiting rooms*. Building Research & Information*, 48(3), 269-85.
- Hoffman, M. (2012). Neural Mechanisms of Place Attachment. *Proceedings of the ANFA Conference—Poster Session; Academy of Neuroscience for Architecture*. CA: La Jolla.
- Hu, M. & Roberts, J. (2020). Built Environment Evaluation in Virtual Reality Environments—A Cognitive Neuroscience Approach. *Urban Science*, (48), 1-16.
- Ijsselsteijn, W.A., de Ridder, H., Freeman, J. & Avons, S. E. (2000). Presence: Concept, determinants and measurement. *Proceedings of the SPIE Human Vision and Electronic Imaging* SPIE: San Jose.
- Ishai, A., Fairhall, S.L. & Pepperell, R. (2007). Perception, memory and aesthetics of indeterminate art. *Brain Res. Bull*. (73), 319–324.
- Jalali Kondori, B., Rahimian, E., Asadi, M. H. & Tahsini, M. R. (2014). Magnetic Resonance Tractography and its Clinical Applications. *The Neuroscience Journal of Shefaye Khatam*, *2*(4), 71-78.
- James, W. (1884). What is an Emotion? *Oxford Journals*, 9 (34), 188-205.
- James, W. (1890). *The Priniples of Psychology*. NY: Henry Holt and Co.
- Jelić, A. (2015). Designing "pre-reflective" architecture. Implications of neurophenomenology for architectural design and thinking. *Ambiances. Environnement sensible, architecture et espace urbain*, (1).
- Hudspeth, A. J., Jessell, T. M., Kandel, E. R., Schwartz, J. H., & Siegelbaum, S. A. (Eds.). (2013). *Principles of neural science*. McGraw-Hill: Health Professions Division.
- Kandel, E.R. (2013). *Principles of Neural Science,* Fifth Edition. New York City: mcgraw hill professional.
- Keil, A., Müller, M. M., Gruber, T., Wienbruch, C., Stolarova, M. & Elbert, T. (2001). Effects of emotional arousal in the cerebral hemispheres: a study of oscillatory brain activity and event-related potentials. *Clinical Neurophysiology*, 112(11), 2057–2068
- Kemeny, M. E., Gruenewald, T. L. & Dickerson, S. S. (2004). Shame as the emotional response to threat to the self: Implications for behavior, physiology, and health. *Psychological Inquiry*, 15(2), 153-160.
- Kircher, T. & David, A. (2003). *The Self in Neuroscience and Psychiatry.* Cambridge: Cambridge University Press.
- Kirk, U., Skov, M., Christensen, M. S. & Nygaard, N. (2009). Brain correlates of aesthetic expertise: A parametric fMRI study. *Brain and Cognition*, 69(2), 306–315.
- Kiecolt-Glaser, J. K., McGuire, L., Robles, T. F. & Glaser, R. (2002). EMOTIONS, morbidity, and mortality: New perspectives

from psychoneuroimmunology. *Annual Review of Psychology*, 53(1), 83.

• Küller, R., Ballal, S., Laike, T., Mikellides, B. & Tonello, G. (2006). The impact of light and colour on psychological mood: A cross-cultural study of indoor work environments. *Ergonomics*, 49(14), 1496–1507.

• Küller R. (1980). *Architecture and emotions.* In Mikellides B. (Ed.), Architecture for people (pp. 87-100). New York, NY: Holt, Rinehart & Winston.

• Küller R., Mikellides B. & Janssens J. (2009). *Color, arousal, and performance - A comparison of three experiments.* Color Res. Appl.

• Klepeis, N. E., Nelson, W. C., Ott, W. R., Robinson, J. P., Tsang, A. M., Switzer, P., et al. (2001). The national human activity pattern survey (NHAPS): A resource for assessing exposure to environmental pollutants. *Journal of Exposure Analysis and Environmental Epidemiology*, (11), 231.

• Kleinginna J. R. P. & Kleinginna A. M. (1981). A Categorized List of Emotion Definitions, with Suggestions for a ConsensualDefinition. *Motivation and Emotion*, 5 (4), 345-379.

• Lang, P. J., Bradley, M. M., Fitzsimmons, J. R., Cuthbert, B. N., Scott, J. D., Moulder, B. & Nangia, V. (1998). Emotional arousal and activation of the visual cortex: an fMRI analysis. *Psychophysiology*, *35*(2), 199-210.

• Lanzetta, J. T., Cartwright-Smith, J. & Eleck, R. E. (1976). Effects of nonverbal dissimulation on emotional experience and autonomic arousal. *Journal of Personality and Social Psychology*, *33*(3), 354.

• Lazarus, R. S. (1991). Progress on a cognitive-motivational-relational theory of emotion. *American Psychologist*, 46(8), 819–834.

• Ledoux, J. E. (2008). Cognitive-Emotional Interactions in the Brain. *Cogn. Emot*, (3), 267–289.

• Leeper, R. W. (1965). Some needed developments in the motivational theory of emotions. In D. Levine (Ed.), *Nebraska Symposium on Motivation*. Nebraska: University of Nebraska Press.

• Liddell, B. J., Brown, K. J., Kemp, A. H., Barton, M. J., Das, P., Peduto, A. & et al. (2005). A direct brainstem–amygdala–cortical ‘alarm’ system for subliminal signals of fear. *NeuroImage*, 24(1), 235–243.

• Linaraki, D. & Voradaki, G. (2012). The Interaction of Space with the Human Nervous System and its Impact on Human Psychology. *Proceedings of the ANFA Conference—Poster Session*. La Jolla: Academy of Neuroscience for Architecture.

• Mulrow C. D. (1987). The medical review article: state of the science. Annals of internal medicine, 106(3), 485–488.

• Malinin, L. H. (2014). Will ‘good’ Architecture make us more creative? Examining the role of place in creative cognition. In *Proceedings of the 2014 ANFA Conference*. The Academy of Neuroscience for Architecture: La Jolla, CA, USA;

• Manganelli, J., Green, K., Brooks, J., Mocko, G., Walker, I. & Healy, S. (2012). Patterns in Architecture, Cognition, Systems, and Software: Representing and Analyzing Cognition during the Design Process. In *Proceedings of the ANFA Conference—Poster Session*. Academy of Neuroscience for Architecture: La Jolla, CA, USA.

• Mavros, P., Austwick, M. Z. & Smith, A. H. (2016). Geo-EEG: Towards the use of EEG in the study of urban behaviour. *Applied Spatial Analysis and Policy*, 9(2), 191–212.

• Meyakawa, K. (1965). Thoughts on Civilization in Architecture. *AD. May*, 229-230.

• Mehrabian, A. & Russell, J. A. (1974). *An approach to environmental psychology*. The MIT Press.

• McDonald, M. W., Hayward, K. S., Rosbergen, I. C. M., Jeffers, M. S. & Corbett, D. (2018). Is environmental enrichment ready for clinical application in human post-stroke rehabilitation? *Frontiers in Behavioral Neuroscience*, (12), 135.

• MURPHY, F. C., NIMMO-SMITH, I. & LAWRENCE, A. D. (2003). Functional neuroanatomy of emotions: A meta-analysis. *Cognitive, Affective, & Behavioral Neuroscience*, 3(3), 207–233.

• Morris, J. D., Klahr, N. J., Shen, F., Villegas, J., Wright, P., He, G.& Liu, Y. (2009). Mapping a multidimensional emotion in response to television commercials. *Human Brain Mapping*, 30(3), 789–796.

• Mulrow, CD. (1987) The medical review article: state of the *science*, 106(3), 485–488.

• Murcia G, Ortiz MJ, Lo´pez-Gordo M.A, Ferra´ndez JM, Sa´nchez Ferrer F, Ferna´ndez E. (2019). Neural representation of different 3D architectural images: an EEG study. Integr. *Comput. Aided Eng,* (26), 197-205.

• Nanda, U., Ghamari, H., Pati, D. & Bajema, R. (2013). Lessons from neuroscience: Form follows function, emotions follow form. *Intelligent Buildings International*, 5(SUPPL1), 61–78.

• Nasar, J. L. (2011). Environment Psychology and urban Design. In T. Banerjee (Ed.), *Companion to urban design*. London: Routledge.

• Neutra, R. J. (1954). *Survival through Design*. New York: Oxford University Press.

• Nidal K. & Malik A. S. (2014). *EEG/ERP Analysis: Methods and Applications*. Boca Raton: CRC Press.

• Nithianantharajah, J. & Hannan, A. (2006). Enriched environments, experience-dependent plasticity and disorders of the nervous system. *Nature Reviews Neuroscience*, (9), 697.

• Noguchi, H. & Sakaguchi, T. (1999). Effect of illuminance and color temperature on lowering of physiological activity. *Applied Human Science*, (18), 117-123.

- Ormandy, D. (2009). *Housing and Health in Europ*e. London: Routledge.
- Ojha, V. K., Griego, D., Kuliga, S., Bielik, M., Buš, P., Schaeben, C., Treyer, L., Standfest, M., Schneider, S., König, R., Donath, D. & Schmitt, G. (2019). Machine learning approaches to understand the influence of urban environments on human's physiological response. *Information Sciences*, (474), 154-169.
- Öhman, A., Flykt, A., & Lundqvist, D. (2002). *Evolutionary perspectives, psychophysiological data, and neuropsychological mechanisms. Cognitive neuroscience of emotion, Series in Affective Science.* Oxford: Oxford University Press.
- Olofsson, J. K., Nordin, S., Sequeira, H. & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology*, 77(3), 247–265.
- Plutchik, R. (1980). *Emotion: A Psychoevolutionary Synthesis*. New York, NY: Harper & Row
- Pallasmaa, J. (2018). *Esencias*. Barcelona: Gustavo Gili.
- Papale, P., Chiesi, L., Rampinini, A. C., Pietrini, P. & Ricciardi, E. (2016). When neuroscience 'touches' architecture: From hapticity to a supramodal functioning of the human brain. *Frontiers in Psychology*,(7),886.
- Pati, D., O'Boyle, M., Hou, J., Nanda, U. & Ghamari, H. (2016). Can hospital form trigger fear response? *HERD*, 9(3), 162–175.
- Pearson, D. (2005). *In Search of Natural Architecture*. Abbeville Press: New York, NY, USA.
- Perry, B.D. (2002). Childhood experience and the expression of genetic potential: What childhood neglect tells us about nature and nurture. *Brain mind*,(3), 79-100.
- Pervin, L. A. (1996). *The science of personality.* New Jeresy: wiley and sons.
- Phan, K. L., Wager, T. D., Taylor, S. F. & Liberzon, I. (2004). Functional Neuroimaging Studies of Human Emotions. *CNS Spectrums*, 9(04), 258–266.
- Pinter-Wollman, N., Jeli´c, A. & Wells, N. M. (2018). The impact of the built environment on health behaviours and disease transmission in social systems. Philos. Trans. R. *Soc. B Biol. Sci.*, (373), 20170245.
- Plutchik, R. (1982). A psychoevolutionary theory of emotions. *Social Science Information*, 21(4-5), 529–553.
- Poels, K. & Dewitte, S. (2006). How to capture the heart? Reviewing 20 years of emotion measurement in advertising. J. *Advert. Res.*, (46), 18–37.
- Pykett, J. (2015). *Brain Culture: Shaping Policy ThroughNeuroscience*. Bristol: Policy Press.
- Radwan, A. & Ergan, S. (2017). *Quantifying human experience in interior architectural spaces.* NY: American Society of Civil Engineers .
- Ray, W. J. & Oathes, D. (2003). Brain imaging techniques. *Int. J. Clin. Exp. Hypn*., (51), 97–104.
- Ranson, R. (1991). *Healthy Housing.* London: Taylor & Francis.
- Reinerman-Jones, L., Cosenzo, K. & Nicholson, D. (2010). Subjective and Objective Measures of Operator State in Automated Systems. In T. Marek, W. Karwowski, R. Valerie, (Eds.) *Advances in Understanding Human Performance. Neuroergonomics, Human Factors Design, and Special Populations*. Boca Ratón: CRC Press.
- Reeve, J., Deci, E. L.. & Ryan, R. M. (2004). Selfdetermination theory: A dialectical framework for understanding the sociocultural infl uences on student motivation. In D. McInerney & S. Van Etten (Eds.), R*esearch on sociocultural infl uences on motivation and learning: Big theories revisited.* V. 4. Greenwich, CT: Information Age.
- Reeve, J. (2009). *Understanding motivation and emotion*. NJ: Hoboken.
- Rheingold, H. (1991). *Virtual Reality: Exploring the Brave New Technologies of Artificial Experience and Interactive Worlds—From Cyberspace to Teledildonics*. NY: Simon & Schuster.
- Roeckelein, J.E. (2006). *Elsevier's Dictionary of Psychological Theories.* Amsterdam: Elsevier Science
- Roessler, K. K. (2012). Healthy Architecture! Can environments evoke emotional responses? *Global Journal of Health Science*, 4(4), 83–89.
- Roe, J. J., Aspinall, P. A., Mavros, P., & Coyne, R. (2013). Engaging the brain: The impact of natural versus urban scenes using novel EEG methods in an experimental setting. *Environ. Sci*, *1*(2), 93-104.
- Rodríguez, A., Rey, B. & Alcañiz, M. (2011). Immersive virtual environments for emotional engineering: Description and preliminary results. *Annual Review of Cybertherapy and Telemedicine 2011*, 199-203.
- Rozin, P., Lowery, L. & Ebert, R. (1994). Varieties of disgust faces and the structure of disgust. *Journal of Personality and Social Psychology*, 66(5), 870–881.
- Rubin, D. C. & Talerico, J. M. (2009). A comparison of dimensional models of emotion. *Memory*, (17), 802–808.
- Russell, J. (1980). A circumplex model of affect. *Personality and Social Psychology*, (39), 1161–1178.
- Sakuragawa, S., Miyazaki, Y., Kaneko, T. & Makita, T. (2005). Influence of wood wall panels on physiological and psychological responses. *J Wood Sci* 51, 136–140.
- Schultz, D. (1976). *Theories of Personality, Monterey*. California: Brooks/Cole Publishing Company.
- Schachter, S. & Singer, J. (1962). Cognitive, Social, and Physiological Determinants of Emotional State. *Psychological Review*, 69 (5), 379–399.
- Schwarz, N. & Strack, F. (1999). Reports of subjective well-being: Judgmental processes and their methodological implications.

Well-Being Found. Hedonic Psychol, (7), 61–84.
- Scherer, K. R. & Shorr, A., & Johnstone, T. (Eds.). (2001). *Appraisal processes in emotion: theory, methods, research*. Canary, NC: Oxford University Press.
- Schwarz, N. & Clore, G. L. (1996). Feelings and phenomenal experiences. In E. T. Higgins & A. W. Kruglanski (Eds.), *Social psychology: Handbook of basic principles*. New York City: Guilford Press.
- Sergerie, K., Chochol, C. & Armony, J. L. (2008). The role of the amygdala in emotional processing: A quantitative meta-analysis of functional neuroimaging studies*. Neuroscience & Biobehavioral Reviews*, 32(4), 811–830.
- Sharma, G., Kaushal, Y., Chandra, S., Singh, V., Mittal, A. P. & Dutt, V. (2017). Influence of landmarks on wayfinding and brain connectivity in immersive virtual reality environment. *Frontiers in Psychology*, (8), 1220.
- Shaver, P., Schwartz, J., Kirson, D. & O'Connor, C. (1987). Emotion knowledge: Further exploration of a prototype approach. *Journal of Personality and Social Psychology*, 52(6), 1061–1086.
- Shemesh, A., Talmon, R., Karp, O., Amir, I., Bar, M. & Grobman, Y. J. (2017). Affective response to architecture – investigating human reaction to spaces with different geometry. *Architectural Science Review*, 60(2), 116–125.
- Shiota, M.N. & Kalat, J.W. (2012). *Emotion*. United States: Wadsworth Publishing.
- Soares, J. M., Magalhães, R., Moreira, P. S., Sousa, A., Ganz, E., Sampaio, A., Alves, V., Marques, P. & Sousa, N. (2016). A hitchhiker's guide to functional magnetic resonance imaging. *Front. Neurosci.* (10), 515.
- Solms, M. & Turnbull, O. (2002). *The Brain and the Inner World: An Introduction to the Neuroscience of Subjective Experience*. London: Karnac Books.
- Sternberg E. M. (2010). *Healing Spaces*. London: Harvard University Press.
- Stichler, J.F. (2001). Creating healing environments in critical care units. *Crit. Care Nurs. Q.*, (24), 1–20.
- Thomson, M., MacInnis, D. J., Park, C. W. (2005). The Ties That Bind: Measuring the Strength of Consumers' Emotional Attachments to Brands. *Journal of Consumer Psychology,* 15(1), 77–91.
- Talarico, J. M. & Rubin, D. C. (2009). Flashbulb memories result from ordinary memory processes and extraordinary event characteristics. In O. Luminet & A. Curci (Eds.), *Flashbulb* memories: New issues and new perspectives. London: Psychology Press.
- Teplan, M. (2002). Fundementals of EEG measurement. *Measurement Science Review*, (2), 1-11.
- Tomkins, S. (1970). *Affects as the Primary Motivational System.* In M. B. Arnold (Ed.), Feelings and Emotions. New York: Academic Press.
- Tracy, J. L., Robins, R. W., & Tangney, J. P. (Eds.). (2007). *the self-conscious emotions: Theory and research.* New York City: Guilford Press.
- Tsunetsugu, Y., Miyazaki, Y. & Sato, H. (2005). Visual effects of interior design in actual-size living rooms on physiological responses. *Building and Environment*, 40(10), 1341-1346
- Ulrich, R.S. (1979). Visual landscapes and psychological well-being. Landsc. *Res*., (4), 17–23.
- Ulrich, R. S. (1981). Natural versus urban scenes: Some psychophysiological effects. Environ. *Behav*., (13), 523–556.
- Ulrich, R. S. (1984). View through a window may influence recovery. *Science* (New York, N.Y.), 224 (4647), 420–421.
- Van Praag, H., Kempermann, G., & Gage, F. (2000). Neural consequences of environmental enrichment. *Nature Reviews Neuroscience,* 1(3), 191.
- Vannucci, M., Gori S. & Kojima, H. (2015). The spatial frequencies influence the aesthetic judgment of buildings transculturally. *Cognitive neuroscienc*e, 5(3-4), 143-9.
- Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Leder, H., Modroño, C., et al. (2013). Impact of contour on aesthetic judgments and approach-avoidance decisions in architecture. *Proceedings of the National Academy of Sciences,* (110), 10446–10453.
- Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Gonzalez-Mora, J. L., Leder, H., … Skov, M. (2015). Architectural design and the brain: Effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions. *Journal of Environmental Psychology*, (41), 10–18.
- Veal, A. (2005). RIBA symposium encourages new links between design and research. Archit. *Res*. Q., (9), 17–19.
- Vecchiato, G., Jelic, A., Tieri, G., Maglione, A. G., De Matteis, F.& Babiloni, F. (2015a). Neurophysiological correlates of embodiment and motivational factors during the perception of virtual architectural environments. *Cognitive Processing*, 16(1), 425–429.
- Vecchiato, G., Tieri, G., Jelic, A., De Matteis, F., Maglione, A. G. & Babiloni, F. (2015B). Electroencephalographic correlates of sensorimotor integration and embodiment during the appreciation of virtual architectural environments. *Frontiers in Psychology*, (6), 1944.
- Vince, J. (2004). *Introduction to Virtual Reality.* NY: Springer.
- Vijayan, V.T. & Embi, M. R. (2019). Probing phenomenological experiences through electroencephalography brainwave signals in neuroarchitecture study. *Int. J. Built Environ. Sustain*, (6), 11–20.
- von Hayek, F. A. (1952). *The Sensory Order.* Chicago: Chicago

University Press.
- Watson, D. & Tellegen, A. (1985). Toward a consensual structure of mood. *Psychological Bulletin*, 98 (2), 219–235.
- Watson, J. B. (1913). Image and affection in behavior. The Journal of philosophy. *Psychology and Scientific Methods*, 10(16), 421-428.
- Wells, A. & Mathews, G. (1994). *Attention and Emotion: A clinical perspective.* Hove: Erlbaum.
- Williams Goldhagen, S. (2017). *Welcome to Your World: How the Built Environment Shapes our Lives.* NY: HarperCollins.
- Williams, J. M. G., Watts, F. N., Macleod, C., & Mathews, A. (1988). *Cognitive Psychology and Emotional Disorders*. Chichester: Wiley.
- Winkielman, P., Berntson, G. G. & Cacioppo, J. T. (2001). The psychophysiological perspective on the social mind. In Tesser, A. & Schwarz, N. (Eds.), *Blackwell Handbook of Social Psychology: Intraindividual Processessychology.* Oxford: Blackwell Publishers.
- Wandersman, A. & Nation, M. (1998). Urban neighborhoods and mental health: Psychological contributions to understanding toxicity, resilience, and interventions. *American Psychologis*t, 53(6), 647–656.
- Yin, J., Arfaei, N., MacNaughton, P., Catalano, P. J., Allen, J. G. & Spengler, J. D. (2019). Effects of biophilic interventions in office on stress reaction and cognitive function: A randomized crossover study in virtual reality. *Indoor Air,* 29(6), 1028-1039.
- Zaltman, G. (2003). *How Customers Think: Essential Insights into the Mind of the Market.* Boston: Harvard Business School.
- Zhang, L., Mike Chi, Y., Edelstein, E., Schulze, J., Gramann, K., Velasquez, A., et al. (2010). Wireless physiological monitoring and ocular tracking: 3D calibration in a fullyimmersive virtual health care environment*. Annual International Conference of the IEEE Engineering in Medicine and Biology Society.*
- Zhang, X., Lian, Z. & Wu, Y. (2017). Human physiological responses to wooden indoor environment. *Physiology & Behavior*, (174), 27–34.

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