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PSYCHOLOGICAL AND PHYSIOLOGICAL EFFECTS OF INTEGRATING BUILDING ENVELOPES WITH PARAMETRIC PATTERNS IN OFFICE WORKERS

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Abstract

The building envelope has become an active element that allows the building to interact with the context of the surrounding environment. The integration of the envelope with architectural design patterns significantly affects the efficiency of the working environment space in the office buildings, where the resulting effect of this integration plays an important role in providing daylighting, visibility and view; which affects the comfort, performance and productivity of users in an office space. This research study aims to identify the physiological and psychological effects on office employees resulting from the integration of the building envelope and openings with one of the most important trends of contemporary architectural design and these are the parametric architecture and parametric patterns. The research sample includes 25 adult office workers (13 men and 12 women) of average age 34.5 ± 9.3years. Skin Conductance (SC) and Heart Rate (HR), were measured to assess physiological responses. Self-Assessment Manikin (SAM) and Short Form State-Trait Anxiety Inventory (SF- STAI) were used to determine psychological responses. The results showed a significant decrease in the mean heart rate values under Repetition and Recursion Pattern (FRA), and a significant decrease in the mean rate of Skin Conductance (SC) response under Repetition and Recursion Pattern (FRA) and Tiling and Subdivision Pattern (VOR) compared to the Baseline model. The study concluded that the influence of the parametric model to the state of valence and calm and reducing the negative feelings and anxiety situation of Office Workers compared to the Baseline model.

Keywords

Building envelope, parametric patterns, office Workers, physiological relaxation, psychological relaxation.

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ABSTRACT

The building envelope has become an active element that allows the building to interact with the context of the surrounding environment. The integration of the envelope with architectural design patterns significantly affects the efficiency of the working environment space in the office buildings, where the resulting effect of this integration plays an important role in providing daylighting, visibility and view; which affects the comfort, performance and productivity of users in an office space. This research study aims to identify the physiological and psychological effects on office employees resulting from the integration of the building envelope and openings with one of the most important trends of contemporary architectural design and these are the parametric architecture and parametric patterns. The research sample includes 25 adult office workers (13 men and 12 women) of average age 34.5 ± ٩.٣years. Skin Conductance (SC) and Heart Rate (HR), were measured to assess physiological responses. Self-Assessment Manikin (SAM) and Short Form State-Trait Anxiety Inventory (SF- STAI) were used to determine psychological responses. The results showed a significant decrease in the mean heart rate values under Repetition and Recursion Pattern (FRA), and a significant decrease in the mean rate of Skin Conductance (SC) response under Repetition and Recursion Pattern (FRA) and Tiling and Subdivision Pattern (VOR) compared to the Baseline model. The study concluded that the influence of the parametric model to the state of valence and calm and reducing the negative feelings and anxiety situation of Office Workers compared to the Baseline model.

KEYWORDS
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1. INTRODUCTION

Spatial experience is one of the dimensions of human existence and it was not only a dimension of thinking and perception, but a fundamental dimension in the guidance, decision-making and various procedures within the surrounding environment (Norberg-Schulz, 1971). Therefore, the schools of

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aesthetic theories dealt with space and its composition as a specific cognitive relationship between a human being and his surroundings (Üngür, 2015), Where the psychology of sensory perception are the mental processes by which we know the external environment through the various sensory stimuli that fall on our senses (Neisser, 2014), And the overall response to those stimuli resulting from the spatial themes and components of the environment is particularly important in guiding the behavior of the individual and modifying it, which is at the same time a response issued by the living organism with all its wealth of memories and experiences and tendencies (Montello, 2002).

Understanding space surrounding us has been a challenge to many different disciplines; architects shape space through the design of buildings and cities, and physiological, environmental and cognitive psychologists and behavioral scientists are looking for how people understand spaces of their content, how they react with them and how they affect them (Barkowsky, Bilda, Hölscher, & Vrachliotis, 2007). However, there is much to be discovered by studying the human response to the design of the surrounding space environment at the behavioral level, and at the level of the biological response to the design, through different methods to measure psychological, sensory, emotional and cognitive interactions with the design.

The architectural spaces alongside their basic utilitarian function to perform a specific activity and function represent a high value because of what can arise and result in multiple effects on the users of those spaces by their composition and formation; whereas interacting with these spaces can move the user to a state rich in sense, thought, and sense of intellectual, psychological and materialistic Valence. the architectural spaces contains many factors that affect the perception and the psychological and emotional state of users, such as the quality and efficiency of natural and artificial lighting, colors and parameters and design parameters of windows and slots, the quality of sight and an external view, which are the most important factors affecting the user whose importance has been clarified and study its impact in a series of previous studies (Abbas, Kumar, & Mclachlan, 2006; Jalili & Sefidi, 2016; Knez & Kers, 2000; Leather, Pyrgas, Beale, & Lawrence, 1998; Veitch & Galasiu, 2011).

Some research on cognitive psychology and neuroscience also pointed to a link between the composition, formation and forms of elements and feelings, where it turned out that Users' personal preferences can be affected by many technical and visual configuration elements (such as symmetry, contrast, repetition, complexity) (Reber, Schwarz, & Winkielman, 2004), for example, people are increasingly preferring symmetrical shapes that contain less detail and information than asymmetric shapes (Garner, 2014).

However, there is still a shortage and scarcity of research on the study of the psychological and physiological effects of trends in contemporary architecture (Such as parametric design and computer aided design), especially regarding the formation of space and how the formation and composition of the determinants of space affect the perception and function, which has not been addressed by any scientific research before.

With regard to the efficiency of space, the design of the building's envelope and the nature of its composition and its integration with design patterns and the shape, size and distribution of external slots affect the efficiency of the internal architectural space, where the effect of this integration plays an important role in protecting the occupants of the building from penetrating direct solar radiation, reducing glare, providing natural lighting, providing visibility and view; acting as a buffer and heat barrier (Mirrahimi et al., 2016) affecting the comfort, performance and productivity of users within space (Sarkar & Bose, 2016).

The climatic region and function of the building are the two most important parameters in terms of the design of the building envelope, and the efficiency of the design of the envelope is affected and thus the efficiency of space is greatly shaped by the formation of the building (Sarkar & Bose, 2016). The building's envelope is divided into opaque elements (which are built mainly of layers of solid materials, such as bricks) and openings or transparent or glazed elements (such as windows). Opaque envelopes usually have a larger thermal mass, higher insulation levels, and more heat retention than transparent or glazed envelopes. In contrast, transparent envelopes usually allow more daylight to interior space and providing a clearer view for the occupants of the place (Aksamija, 2013). Architects use many tools that work with computer-aided graphics to achieve efficient designs of building envelopes, these tools help designers to visualize different design models.

Since changing any part of the design requires extensive modifications to many parts and other design components. Designers, therefore, looked for software to help solve this problem and allow the creators to change a few parameters followed by an automatic change in the components of the

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designed model, which in turn the design update itself according to the changed variables, thus we call this process parametric design (Jabi, 2013)

The term "parametric" is derived from the term "parameter", Thus the design process is to identify the problem and then try to find suitable alternatives to solve that problem. So the parameter is defined as any measurable factor that limits or restricts the system (Terzidis, 2009). In turn the parametric design can thus be understood as a process of describing the problem using variables, then it illustrates a range of alternative solutions when changing those variables and after that it chooses the suitable solution based on the criteria we set, thus the parametric model can be defined using a specific programming language (Hudson, 2010).

Software companies have developed many visual programming tools that are targeted to non-specialists such as architects with limited software skills, allowing them to interact with digital objects, especially through node-dependent graphic systems. The Grasshopper software system, presented by Robert McNeel and Associates, Is one of the most important programs that allowed designers to build complex and advanced systems and structures by linking the parametric foundations based on the visual translation of the node-dependent graphic system algorithms (McNeel, 2010).

The integrated architectural parametric patterns with building envelopes result from the usage of these programs which in turn represent a powerful tool of architectural expression (Schumacher, 2009; Vlissides, Helm, Johnson, & Gamma, 1995). Though parametric design patterns are still under development, Robert Woodbury and his team have combined a comprehensive set of parametric patterns with a consistent template, and systematically developed them, and published some of these patterns in their book, "Elements of Parametric Design" (Woodbury, 2010). Benjamin Aranda and Chris Lash presented a set of advanced and exciting styles in their book "Tooling", which offers highly advanced, highly accurate and high-level parametric structures such as "spiral shapes, cracks, and leaks" (Aranda & Lasch, 2006). In addition, Jane Burry and Mark Burry organized chapters of their book "New Mathematics of Architecture" according to parametric themes such as "tiling and topology" (Burry & Burry, 2010). Wassim Jabi has developed many models and algorithms that have followed high-level strategies aimed at deriving an integrated form and definition of parametric pattern topologies, all of his results were presented in his book, "Parametric Design in Architecture", which is one of the most important contemporary scientific references in parametric design and explains its basic patterns and methods of manufacturing and derivation (Jabi, 2013).

The current research study was based on all the results of previous studies and references in order to identify and define all the most common architectural parametric patterns of structures with parametric building envelopes to arrive at a specific and fundamental range of these parametric patterns and a set of design alternatives that can be tested and compared with different effects on the user within the building space. And based on the following, the research problem is that future and contemporary architectural trends are expanding and reaching complex spatial levels of parametric design, thus the building envelopes over time will get more morphologically complex due to the rapid development in software capabilities and designing tools, Without considering in-depth studies of the integrated architecture expected effects “psychological and physiological” on their users, which interact with contemporary environmental conditions, especially in hot dry desert areas that have not received sufficient attention and study research for those future trends.

In addition, many space users spend a lot of their day in office buildings where humans spend the most of their total annual wake-up hours (Ikei, Komatsu, Song, Himoro, & Miyazaki, 2014), Previous studies have indicated increased levels of stress among office workers, And that the stresses in the work not only cause psychological symptoms but also physiological as they increase the risk of infection with various diseases such as heart disease and blood vessels (Kang et al., 2005); As many office workers work in highly stressful environments, the alleviation of this situation is necessary and urgent.

Here the role of construction of the external building envelope in office buildings is to influence the quality of the interior environment, and thus on the various aspects of human performance whether materiality (represented by identifying the style of functionality and efficiency) or non- materiality (represented by the psychophysical impact of space and envelope on the human and increase his happiness , comfort and reduce stress), and the linkage of these aspects directly, especially in the impact of non- materiality and psychophysical aspects on the materiality aspects and productivity of workers within office spaces or even in their daily lives after leaving their working environments (Aries, Veitch, & Newsham, 2010; Boyce, Hunter, & Howlett, 2003).

Therefore, for effective use of buildings, it is important to have objective measurements as well as self-measurements of these effects on human health and well-being. Thus, when parametric design patterns are integrated with office building envelopes without sufficient study of psychophysical effects; It may produce negative effects and consequences that affect users ' health or productivity within space, and can be positive and increase comfort, happiness and reduce stress among office workers.

Through the previous presentation of the research problem, prior to the start of the research study, it was necessary to formulate the hypothesis that would be tested through statistical tests. Here is put up the null hypothesis (H_0) and the alternative hypothesis (H_1), the research null hypothesis requires that there is no assured link or relationship between the parametric model and the Baseline model of the research study, while the alternative hypothesis requires that there is a direct relationship between the integration of parametric patterns with the envelope and between the statically significant differences in the values of the psychometric and physiological measurements that were used in the study and resulting from these patterns for the occupants of the office and administrative spaces compared to the Baseline mode of space envelopes without any parametric patterns in a hot dry climate.

This research study aims to identify the expected psychological and physiological effects of integrated parametric patterns with the office envelope for adults working at offices in a hot dry desert regions; Thereby increasing the health and well-being of office workers and reducing their stress, as well as helping to provide objective rationality for selecting and identifying appropriate parametric patterns for envelopes of the working environments by architectural engineers.

Skin Conductance (SC) and Heart Rate (HR), were measured to assess physiological responses. The measurements were used to measure the effects of physiological relaxation to display different parametric patterns on the autonomic nerve activity. Self-Assessment Manikin (SAM) and Short Form State-Trait Anxiety Inventory (SF- STAI) were used to determine psychological responses. They have been used as measurement mechanisms in many previous studies and research literature to study the physiological and physiological effects of various environmental influences and stimuli to users to identify autonomic nervous system indicators of Arousal, stress and tension rates. They have been used as measurement mechanisms in several previous studies and research literature on the study of scientific and physiological influences of different environmental influences and stimuli to users to identify the indicators of the nervous system from the rates of Arousal, stress and tension (Abbas et al., 2006; Igarashi et al., 2015; Ikei et al., 2014; Kuijsters, Redi, de Ruyter, & Heynderickx, 2015; Lazarus, Speisman, & Mordkoff, 1963; Nikula, 1991; Song et al., 2013). The increased value of skin behavior response and the increased heart rate are also associated with the increased Arousal rate (Gomez, Zimmermann, Guttormsen Schär, & Danuser, 2009; Lang, Greenwald, Bradley, & Hamm, 1993).

2. MATERIALS AND METHODS

2.1 Parameters for the design of integrated parametric pattern models with the building envelope

A set of basic parametric patterns - the design alternatives used in the research study - were chosen as the most common design patterns of integration with the building envelope (Force Field Pattern - Repetition and Recursion Pattern - Tiling and Subdivision Pattern - Packing pattern - Controlling and Transforming Pattern). All the patterns used by Grasshopper were designed, modeled and formulated within the Rhinoceros platform, which represents the most important parametric design software.

The digital fabrication process was carried out by selecting the suitable material for manufacturing; it is Foam PVC material which was chosen to suit the parametric design for its ease of use, manufacturing, flexibility, lightweight and strength as well as being a sustainable recyclable material. The material was cut through the digital fabrication machines (Laser Cutting Machine) and chooses the largest possible size of a piece of dimensions ٢٤٠*١٢٠ cm to ensure its quality and to maintain its design beauty and installation directly on the envelope of case study. After the cutting operations, the panels were processed and cleaned. After long-time cutting, the plates were processed, cleaned, packaged and then shipped to the experiment research site. And there have been started initializing and processing spaces, to fix the panels on

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the glass facade for the building space of the experiment space (as shown as Fig. 1) in a flexible way that allows for changing patterns during the work of the research experiment.

Fig. 1 Experimental setting. Space processing before installation of parametric pattern on the envelope of the office space.
Reference: Photographed by author 2017

Fig.2 illustrates the structure and design of all the basic parametric patterns used in the study. It also illustrates the effect of the integration architecture of each parametric pattern with the building envelope on the atmosphere and nature of office space, especially in relation to direct solar radiation rates and the distribution of daylighting and engineering configurations resulting from the distribution of shade and light within space, especially in space facing the user's office. The code of each variable is derived from the nature of the parametric pattern that is configured. For example, the parametric configuration resulting from the Tiling and Subdivision pattern is the “VOR” code derived from the resulting configuration of the pattern is VORONOI geometry configuration.

Fig. 2 Structure of all basic parametric patterns integrated with the envelope of the of the office space.
Reference: Designed by the author

2.2 Climate, geographical and environmental determinants

The site of the research study was chosen in accordance with the study's determinants and objectives within the research scope of the study which is of the hot desert-dry climate region in Al-Khobar city in one of the office spaces inside the building of Sumou Company. the standard vacuum in which the research experiment was conducted was chosen at an appropriate height from the surface of the earth (32 meters), in accordance with the limits of the quality of daylighting such as ensuring that there are no external obstacles to achieve the requirement of neutrality in the access of the natural light vehicles inside the vacuum and not to obstruct, and to ensure a good view of the outside which includes the skyline of the city with all its high buildings and main roads and residential areas and green.

Fig.3 shows the plan of office space, the section and the monitoring points of environmental rates during the experiment, The experiment was conducted in April under the conditions of stability of all external environmental determinants under standard conditions of the sunny net without clouds, under normal space conditions, where the average room temperature was 27.5 ° C, the average light intensity 506 lux, the natural light factor 2.96%, the actual internal humidity ratio 60% and the operation of the fan system only to allow the thermal effect of different parametric patterns to users. Space is 10 square meters, the net height is 3 meters ,the windows to the walls ratio (WWR) is 30%, the glass, is double glass, transparent, uncoated, of thickness 18 mm, the interior is neutral white, and the surface height is 80 cm.

Fig. 3 The plan and the section of the office space, and the positions of observation points for monitoring all environmental measurements during the research experiment.
Reference: The author

All conditions of the experiment have been considered to be stable as possible during the measuring process, where any change of the experiment physical and environmental conditions may effect on the accuracy of the results, including external environmental conditions, such as the stability of the daylight factor, skydome and weather conditions .

Therefore, due to difficulty of achieving that and applying it on all participants in case the experiment is undertaken during one day only, due to the great contrast of shadow and light composition and the changes of daylight coefficients during the periods of early morning, morning, noon and afternoon according to the observation in experimental preview phase of the space before undertaking the experiment. The experiment has been undertaken during three consecutive days, considering the stability of all external and internal environmental conditions. The experiment has been also undertaken during afternoon only, considering building orientation and sun path diagram during three days to ensure converging solar angles and undifferentiated influences of shadow and light composition within space on all participants.

2.3 Users

In this research, the experimental sample method is used which is subjected to trial and experimentation based on the presentation of the experimental or exciting or influential, and evaluate the experiment in terms of quantity and quality, for comparing the results of the effects. Since there are several types of experimental sample, in relation to the control group according to the Campbell and Stanley studies, the one experimental group method that does not exist in the control group is used, where it depends on the test method for the same group before and after the application (Campbell & Stanley, 2015).

In the experimental study, the independent experimental and influencing variable would be the parametric patterns; the dependent variable is the psychophysiological measurements of the users, given the stability of the other conditions. the absence of any extraneous or confusing variables that may interfere with the independent variable and its competition in influencing the dependent variable; in order to conduct controlled experiments to determine physiological changes resulting from people's exposure to the different conditions of parametric patterns to ensure that the changes recorded are the result of the effect of parametric patterns only.

The research sample included 25 adult office workers (13 male and 12 female) with an average age of 34.5 ± ٩.٣years. All participants had university degrees with no MSc or PhD, and all of them working full time. None of the persons reported any physiological or psychological disorders or chronic organic diseases in their personal history and were not under any medication that might affect their mental and neurological activities. In addition, none of the women participants were in pregnancy on the day of the experiment, excluding all participants who had smoking habits. All participants were informed of study protocol for inclusion before they participated in the study and their participation was voluntary. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Mansoura University in Egypt.

2.4 The followed procedures:

All participants were assembled in the waiting room for 20 minutes before the starting time. After going to the experiment for each individual user, Physiological measuring devices were connected and installed on the measurement position in the users' bodies within space and the measuring and recording of the five-minute rates for the Baseline model being initiated, and then expose the research sample to five scenes of different parametric patterns for five minutes for each pattern, separated between each pattern and the other three minutes for relaxing the user, with wearing a mask for the eye , the internal air of the room is renewed by opening the door for a minute during the installation of the pattern, the research sample of space users is required to complete the models of psychometric measurements, this is done after taking physiological measurements for each pattern of the different patterns of parametric design. The experimental setting for the parametric patterns is shown in Fig.4.

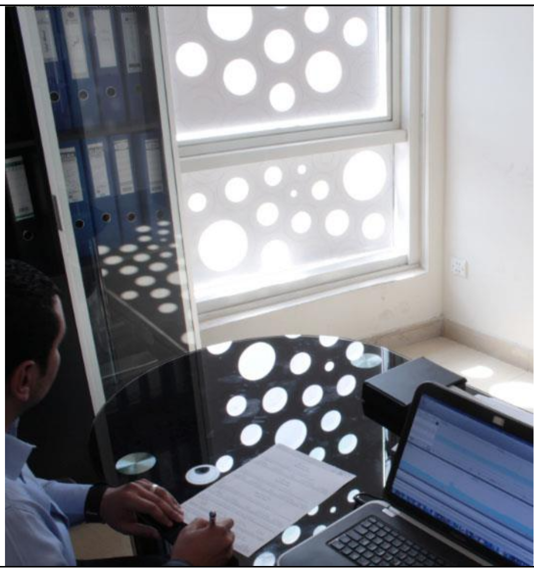


Fig. 4 physiological indications of a subject sitting in the viewing area of the parametric pattern. Reference: Photographed by author 2017

2.5 Physiological and Psychological Measurements:

The measurement mechanisms used for physiological indicators include the Galvanic Skin Response (GSR) or the Skin Conductance (SC) through the (AFFECTIVA Q Sensor) , which was created through several scientific researchers at the Massachusetts Institute of Technology (MIT) (Kappas, Küster, Basedow, & Dente, 2013), it is a very small device installed in an area below the forearm which is one of the most accurate points to measure the electrical skin response, in addition to using a special program connected to the device to obtain data, which is the Q live program associated with the device, through which all the real results, values and graphical indicators are reviewed.

The heart rate was measured by measuring the movable heart rate monitor (Beurer BC40). All measurements have been recorded through the devices for recording the physiological variables and indicators of the body when exposed to different models of parametric patterns under the study. Physiological measurements were collected along the duration of exposure to each pattern for 5 minutes to measure Skin Conductance and for 1 minute at the end of exposure to each pattern. Fig.5 shows the devices used in physiological and environmental measurements.

Two different questionnaires were used to investigate psychological responses, which were completed after physiological measurements were finished for each effective model and pattern. The participants completed the Self-Assessment Manikin (SAM) through the direct measurement of bilateral emotional dimensions, which is the Valence and Arousal (Bradley & Lang, 1994), Which consists of five graphical scores as a measure of assessment ranging from very negative to very positive (Bradley & Lang, 2000), and then the 5-point scale is converted to the following grades (Scheumann, Hasting, Kotz, & Zimmermann, 2014): -2 (very negative), -1 (negative), 0 (neutral), 1 (positive), 2 (very positive). Through this way, the average degree of measurement of the Valence and Arousal of all participants is calculated.

The short model of the anxiety state (SF-STAI) was used (Marteau & Bekker, 1992), which includes measuring 6 elements that reflect and equivalent to the original elements to be measured in the original system, which includes measuring the following emotions (calmness, tension, tightness, relaxation, anxiety, satisfaction, or reassurance) on a scale consists of four degrees with a total score of between 20 and 80 (Bekker, Legare, Stacey, O'Connor, & Lemyre, 2003), They are calculated through the calculation model of measurement and higher scores reflect increased levels of anxiety.

Fig. 5 The devices used in physiological and environmental measurements (1) Affectiva Q Sensor (2) Heart Rate monitor (3) illuminance monitor (4) The weather station.
Reference: Photographed by author 2017

2.6 Statistical analysis of results

The Statistical Package for the Social Sciences (SPSS) was used, using a single-variance analysis test (One-Way ANOVA) to determine whether the change in the values of the physiological and psychological measurements under the influence of the different parametric patterns is statistically significant compared to the Baseline model.

The changes in the nature of physical properties of materials integrated with the envelope, or even replacing these materials itself, may directly, or indirectly, effect on the psychophysiological measurements of participants. However, in accordance with the nature and objectives of this study and previous research studies, single-subject design has been applied (the subject is subjected to the experiment, statistical analysis and testing depending on the independent variable, experimental data, stimulus, or influences), assessing the experiment for the same subject before and after experimenting. Then, compare the results of both pretest and posttest groups according to the scientific method used by Stanley and Campbell research design.

In our experimental study, the experimental independent variable and influences were only parametric patterns, and the dependent variable – the variable measured at the end of the experiment to examine how it's effected by independent variable – was the psychophysiological measurements of participants, while ensuring that extraneous variables have no influence. These extraneous variables include all variables related to the determinants of internal environment effecting the studied space, which form the physical properties of materials of the envelope, and even the vertical and horizontal determinants of the space.

The single-variance analysis test was used as a method to test the significance of the difference between the averages of several samples by one comparison and in a way that divides the total differences of the set of experimental observations for several parts to identify the source of the difference between them. The objective is to examine the sample variance to determine the extent of the sample mean equality after ensuring that all samples are independent and with normal distribution.

All final statistical values were presented in the statistical tables, namely the mean value for all the psychophysical measurements of all users under the influence of each parametric pattern, and the probability value (P-Value) was statistically significant at the acceptance level (0.05), and all data were presented as mean ± the Standard Error of the Mean (SEM).

3. RESULTS

3.1 Physiological Effects

When comparing physiological indicators between the Baseline model and the parametric model, the following major differences were observed. Fig.6 shows the heart rate during exposure to different Baseline and parametric models. The heart rate in the FRA-pattern (68.4 ± 1.8 beats per minute) was statistically significantly lower than the Baseline model (74.3 ±1.9 beats per minute, p <0.05);Note that the heart rate of the rest of the parametric patterns was slightly less statistically insignificant than the beats rate of the Baseline model where the rates for all parametric patterns are ATT (73.2 ± 1.8 beats per minute), TRA (74.0 ±1.8 beats per minute) , PAC (71.68 ±1.8 beats per minute) and VOR (71.5 ± 1.6 beats per minute).

Fig.7 shows the Skin Conductance (SC) response rate during exposure to different Baseline and parametric models. The Skin Conductance response rate in the FRA-pattern (0.26±0.04 microsiemens) and the VOR-pattern (0.25±0.04 microsiemens) were significantly less than the Baseline model (0.53 ± 0.11 microsiemens, P <0.05). The response rate of the TRA pattern (0.29±0.05microsiemens) was marginally significantly lower than the Baseline model, Note that the response rate for the rest of the parametric patterns was slightly less statistically insignificant compared to the Baseline model where the rates for all parametric patterns are ATT(0.34±0.06 microsiemens) and PAC(0.31±0.06 microsiemens).

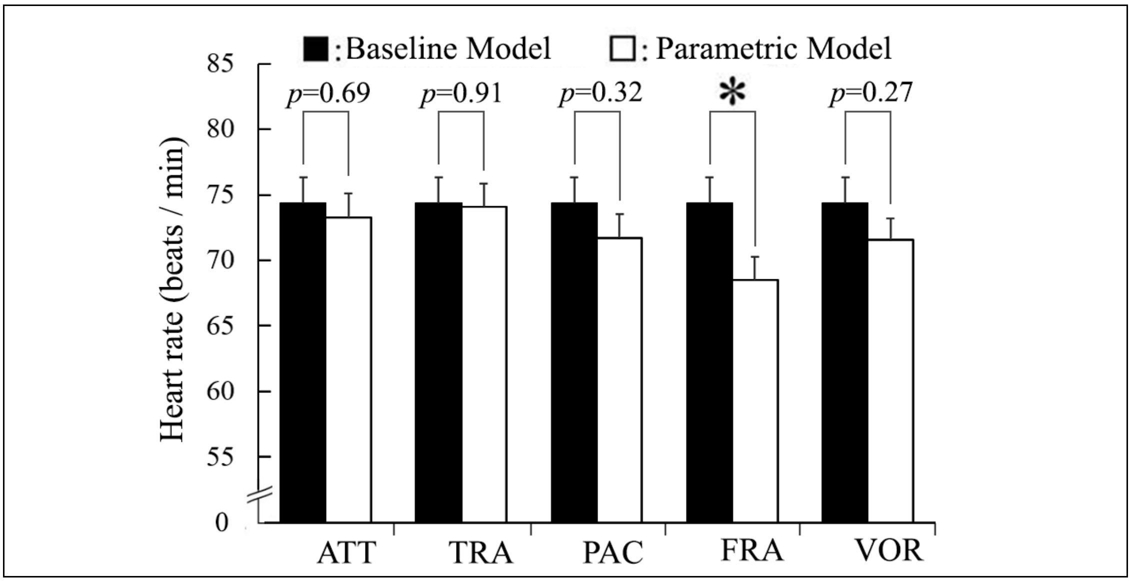


Fig. 6 Comparison of the heart rate during viewing of the Baseline model and the parametric
*P <0.05; single-variance pattern models. Data are expressed as the means ± SE; n = 25.
analysis test (one-way, ANOVA).
Reference: Analysis by the author

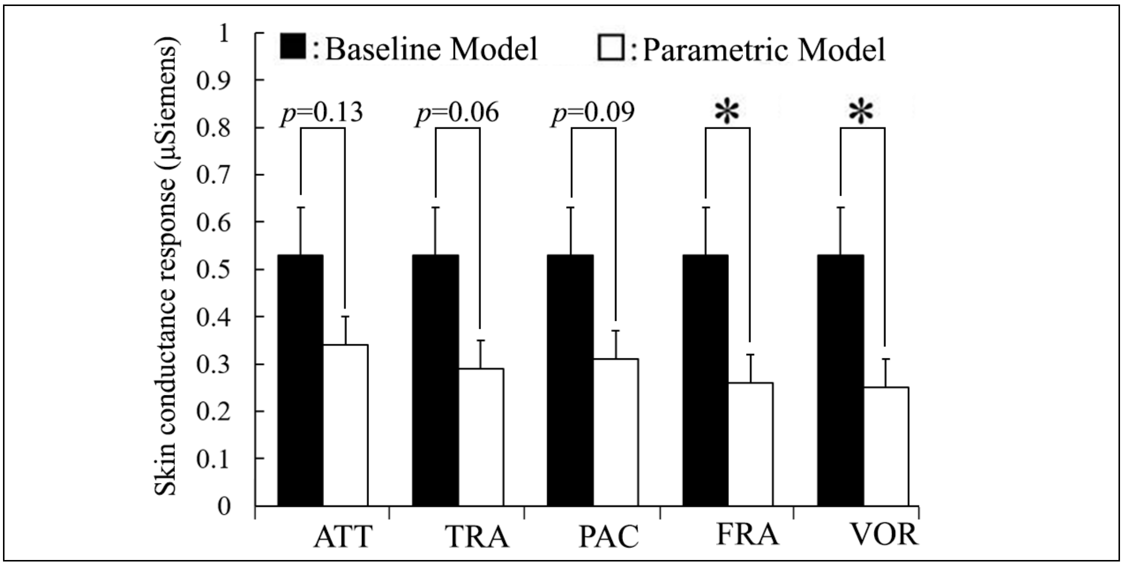


Fig. 7 Comparison of the skin conductance during viewing of the Baseline model and the
*P <0.05; single- parametric pattern models. Data are expressed as the means ± SE; n = 25.
variance analysis test (one-way, ANOVA).
Reference: Analysis by the author

3.2 Psychological Effects

Fig.8 and Fig.9 show the results of the SAM test, through which the basic emotional dimensions have been directly measured, namely Valence and Arousal, which represent the emotional responses of users towards the effect of the Baseline model and basic parametric patterns.

Fig.8 of the results of the Valence test shows that the Valence scores in the FRA-pattern (0.64±0.22 scores) and the TRA-pattern (0.68±0.22 scores) are statistically significant higher than the Baseline model (-0.08±0.16 scores), p <0.05). The response rate for the rest of the parametric patterns was slightly higher than statistically insignificant compared with the Baseline model, where the rates for all parametric patterns are ATT (0.24±0.22 scores), PAC(0.24±0.23 Scores) and VOR (0.32±0.2 scores).

Fig.9 of the results of the Arousal test shows that the Arousal scores in the FRA-pattern (0.52±0.23 scores) and the TRA-pattern (0.52±0.20 scores) are statistically higher than the Baseline model (-0.20±0.25 scores, p <.05). The response rate for the rest of the parametric patterns was slightly higher, statistically insignificant compared with the Baseline model, Where the rates for all parametric patterns are PAC (-0.04±0.21scores) and VOR (0.24±0.21scores), While the ATT-pattern achieved, a statistically significant decrease (-0.28±0.25scores) compared to the Baseline model.

In the anxiety analysis results (as shown as Fig.10), the result of the ATT-pattern (38.66±2.42 scores) less statistically significant than the Baseline model (46.66±2.72 scores, p <0.05); and the FRA-pattern (37.6±1.71 scores) less statistically significant than the Baseline model (46.66±2.72 scores, p <.01). While the response rate for the rest of the parametric patterns was found to be slightly less statistically significant than the Baseline model, where the rates for all parametric patterns reached to TRA (41.06±2.09 scores),PAC (41.06±2.62 scores), VOR (42.4±2.51 scores).

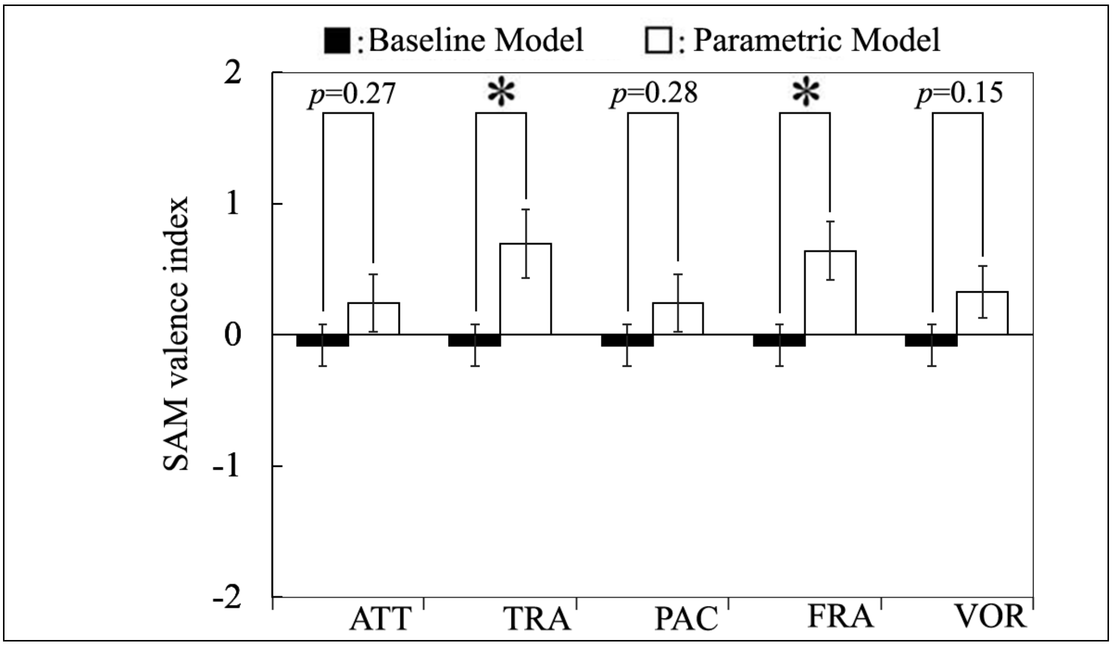
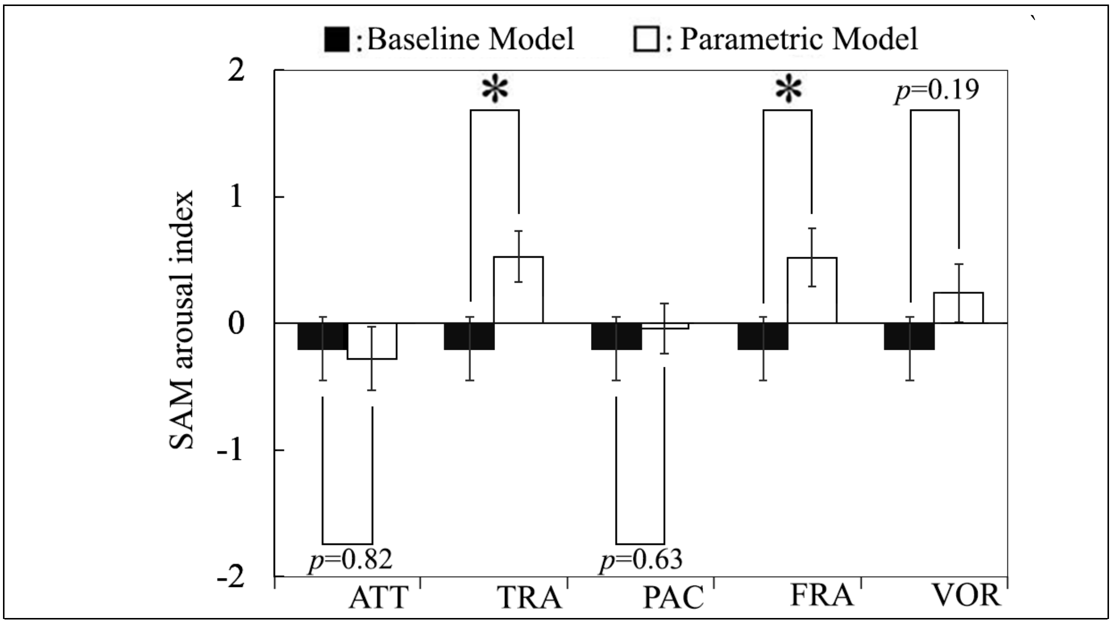


Fig. 8 Comparison of the SAM valance index during viewing of the Baseline model and the parametric pattern models. Data are expressed as the means ± SE; n = 25. *P <0.05; single-variance analysis test (one-way, ANOVA). SAM, Self-Assessment Manikin.
Reference: Analysis by the author

Fig. 9 Comparison of the SAM valance index during viewing of the Baseline model and the parametric pattern models. Data are expressed as the means ± SE; n = 25.*P <0.05; single-variance analysis test (one-way, ANOVA). SAM, Self-Assessment Manikin.
Reference: Analysis by the author



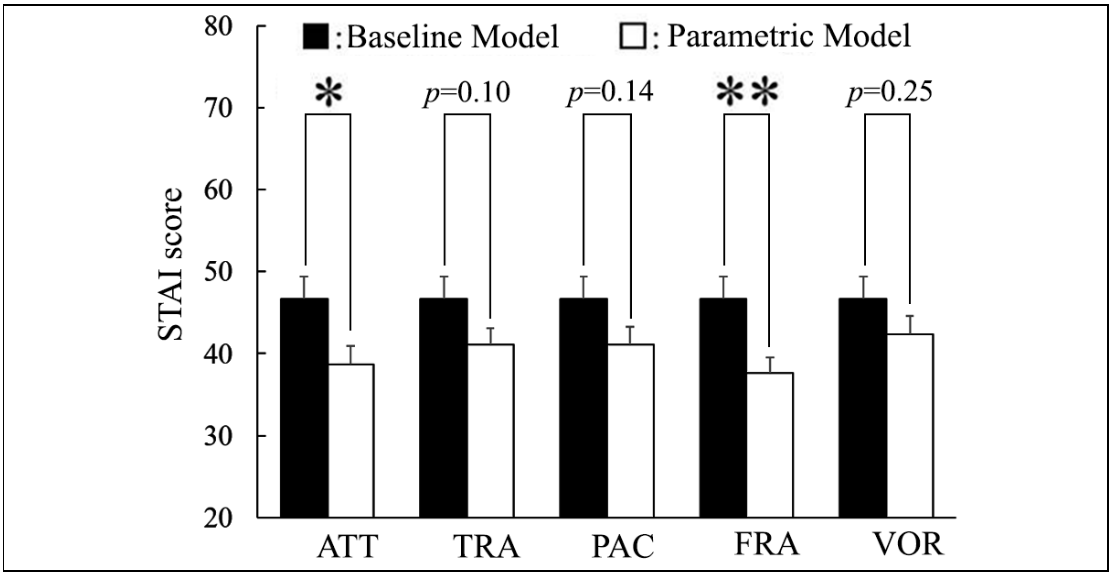


Fig. 10 Comparison of subjective scoring for state anxiety by STAI between the Baseline model and the parametric pattern models. Data are expressed as the means ± SE; n = 25. **P <0.01;*P <0.05; single-variance analysis test (one-way, ANOVA). STAI, State-Trait Anxiety Inventory. Reference: Analysis by the author

4. DISCUSSION

The results of the current study show decreased heart rate under the influence of different parametric patterns. It was also noted that the FRA-pattern led to the largest decrease in the overall average heart rate for all users. Thus, the observation directly confirms that changing the parametric pattern and configuration causes a change in the heart rate due to a change in the emotions of users within space. By looking at the results of the conductivity skin analysis, We find that the results confirm directly that changing the pattern and the parametric composition, causing a change in response of skin conductivity, which is due to a change in the emotions of users within space; Especially in the case of low rate, which reflects the reduction of negative emotions , calm, comfort and stability of users compared to the Baseline situation, which recorded the highest value that indicates the highest level of Arousal and irritation.

By analyzing the results of the Self-Assessment Manikin for the Valence category; the ATT-pattern have achieved the largest mean of Valence values for all users where they reached 0.68, also the parametric patterns ATT and PAC have achieved the lower mean values of Valence in parametric patterns for all users where they reached 0.24. Here it is noted that all values recorded for the mean of parametric patterns, even the lowest values are positive values, thus achieving a good psychological impact on users with respect to the high or moderate Valence values of parametric patterns in general compared to Baseline mode. By analyzing the results of the Self-Assessment Manikin for the Arousal category; the parametric patterns TRA and FRA have achieved and the largest mean of Arousal values for all users where they reached 0.52, also the ATT- pattern has achieved the lower mean of Arousal values for all users where they reached -0.28.

By combining the results of the self-assessment model of Arousal and Valence, It is noted that the higher parametric patterns in the values of the Valence parameter and the Arousal parameter and statistically significant are TRA and FRA, they both have achieved positive values for the general mean for users; Thus, according to the graphical representation of the circumplex model of affect and the relationship between (Valence-Arousal) (Valenza, Allegrini, Lanatà, & Scilingo, 2012), the resulting value of the relationship is in the positive quarter of the positive direction of horizontal axis (representing the valence dimension) and the positive direction of the vertical axis (representing the arousal) , which expresses the access of users within space to the state of happiness and cheering.

In addition, negative emotions and anxiety levels were significantly lower in most of the parametric patterns, with the realization of the FRA-pattern of positive results in all psychological measurements, which confirms that using the pattern leads to the occurring of good and effective psychological effects on space users.

The effects of physiological and psychological relaxation associated with user exposure in the office spaces of parametric patterns have been clearly demonstrated in this study. The results also show that the integration of some parametric patterns with the envelope of the building led to the greatest positive results in all psychophysiology measurements, as what was achieved in the FRA-pattern where achieved the best results were significant in the overall result in all measurements. It confirms the validity of the alternative hypothesis (H1) which states that there is a direct relationship between the integration of parametric patterns with the envelope and between the statically significant differences in the values of the psychometric and physiological measurements that were used in the study and resulting from these patterns for the occupants of the office and administrative spaces compared to the Baseline mode of space envelopes without any parametric patterns in a hot dry climate.

Therefore, the study recommends the need for integration with the envelope of the office buildings through the direct external treatments integrated with the type of external glazing, whether they are single glazing or double glazing (such as the current research study).

The current research study has covered many disciplines according to many research determinants and according to a special research methodology; And led to many conclusions and raised a range of different questions that need to expand the scope of the study by changing the determinants of research or methodology or independent or dependent variables, whereas there are many of those aspects that cannot be covered through a single research study, especially in the field of psychometric or physiological studies. Therefore, the results of the present study cannot be extrapolated for office employees outside the determinants of the study. To disseminate results to all types of office spaces, further evidence-based studies are needed for a large sample, including different thematic groups of different age groups, in different climatic regions, and they can be applied to users of spaces not covered by the current study Such as healthcare or educational spaces.

5. CONCLUSIONS

The results of the research study indicate a significant decrease in Heart Rate (HR) under the influence of Repetition and Recursion Pattern (FRA), the best positive significant results in all psychophysiology measurements. The results also indicate a significant decrease in the mean rate of Skin Conductance (SC) response under the influence of Repetition and Recursion Pattern (FRA) and

Tiling and Subdivision Pattern (VOR) compared to the Baseline model. The results also confirm the existence of a direct relationship between the integration of the parametric patterns with the envelope of the office building and the occurrence of positive differences with significant statistical in the values of the psychometric and physiological measurements resulting from those patterns for the occupants of the office spaces compared to the Baseline situation of the envelope without any parametric patterns in the a hot dry climate.

ABBREVIATIONS

HR: Heart rate; SC: Skin conductance; SAM: Self-Assessment Manikin; STAI: State-trait anxiety inventory; ATT: Force Field Pattern; FRA: Repetition and Recursion Pattern; VOR: Tiling and Subdivision Pattern; PAC: Packing pattern; TRA: Controlling and Transforming Pattern.

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AUTHOR CONTRIBUTIONS

AR contributed to the study design, data acquisition, statistical analysis, interpretation of the results, manuscript preparation, the design of parametric patterns and all processes of digital fabrication and the creation of the research space. LG and SS were involved with data acquisition and statistical analysis, interpretation of the results and manuscript preparation. All authors contributed to the preparation and are responsible for the final editing and approval of the manuscript.

This work has been conducted and supervised by academic architectural researchers with a vast experience and related researches, which, and this paper, witnessed the collaboration of researchers from different majors of physiological psychology; to learn how various psychophysiological measurements are conducted, and how to read and analyze the readings of used instruments. In addition to researchers' studies integrated with this field based on all relative specialized medical references.

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