Rhythm Phenomenology in Architecture and Building Design

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ABSTRACT

Rhythm is one of the most essential means of coordination in architecture because it guarantees the orderly distribution of forms and spaces. Consequently, the research problem was: "The lack of a comprehensive understanding of the origins and applications of rhythm as a recognized phenomenon in architectural design." The research aims to "understand the phenomena of rhythm in the formation of architectural products and to identify their types and orientations. The research adopts a descriptive-analytical methodology to clarify the phenomenon of rhythm in architecture by constructing a cognitive framework, followed by a comprehensive theoretical framework extracted from the architectural literature and embodied in its final form as three main terms: "Types of rhythm in architectural design, its determinants, and its trends. The study's most significant findings are that rhythm in architecture refers to the repetition of elements such as lines, shapes, and hues, which results in an organized movement through space and time. To accomplish rhythmic unity, the application results revealed that architects favored "rhythmic alternation, rhythmic gradation, and rhythmic contrast" over "monotonous and disorganized rhythm."

KEYWORDS: Rhythm; Repetition; pattern; Phenomenology; Design cognition; Design thinking.

1. INTRODUCTION

Humans appreciate cadence in numerous fields, including music, art, architecture, and nature. Rhythm is one of the architectural elements that contribute to the atmosphere of a building. When specific elements are repeated in a work of art, such as music, poetry, painting, or architecture, the audience experiences a sense of movement and cadence (Munch, 2021). There is a connection between rhythm and nature, rhythm and evolution, and rhythm and emotion because rhythm is essential to the human condition. Architects typically incorporate a unifying motif inside and outside a building to improve its aesthetic appeal (Shine et al., 2019). Humans appreciate cadence in diverse domains, including nature, art, poetry, music, and architecture (Munch, 2021). According to Shine et al. (2019), human cognition is the source of design. Every designer has a method of thinking and diverse perspectives, backgrounds, and design approaches (Greenbaum & Kyng, 2020). This makes each designer's work distinct and individual. Although every designer creates something unique, certain phenomena tend to recur and eventually assume specific forms (Conforti, 2019). Some of them are visually enticing and attractive due to the unique qualities of their visual expressions. During creation, distinctive compositional techniques are utilized to achieve these aesthetic qualities. Some of these phenomena could be analyzed, measured, and observed to gain a thorough comprehension of the design creation process and design quality. In product design, human perceptions recognize rhythm as a distinct pattern (Bauer et al., 2021).

2. RHYTHM IN NATURE

Human society is a component of the natural world in which we exist. According to the laws of physics, every natural process tends to run down and cease because the energy behind it is depleted in overcoming resistance. Then it transforms into a different form. And that composition is an aesthetic appeal to human senses, so nature gave us the "Law of phyllo taxis," a derivative of "Spiral Theory," whose concept still exists in the vast majority of vegetative shoots and natural phenomena, where "Helical Development" appears in the growth property known as "self-similarity or scaling," that is, growth in size while maintaining the same shape (Greenbaum & Kyng, 2020).

Practically, the architecture of all plant structures, whether densely "content" packed pine, sunflowers, or cedar, or evident "cortical" leaves, stem bark, are susceptible to the Fibonacci numbers regularity. In this manner, the "Fibonacci triple" pine cones are spiral-shaped, with 8 spirals in one direction and 13 in the other. In addition, sunflowers have a spiral seed arrangement. The pineapple comprises contiguous hexagons and three types of three-dimensional spirals: "8 on the right, 13 to the left, and 21 vertically." Thus, biological advantage enables fruits to "package "maximum seeds" into heads" and promotes the progressive growth of other plant parts according to their occupying "place and processing" (Conforti, 2019; Holtzen et al., 2022).

According to Lane et al. (2023) rhythm is fundamental to human nature because nature, evolution, and emotion are all associated with rhythm (Lane et al., 2023). Adapting one's behavior to external stimuli necessitates manifesting relevant sensory information over time (Zalta, Petkoski, & Morillon, 2020). This capability requires the ability to alter and adapt flexibly to the natural temporal dynamics of the environment. For instance, in an exuberant jazz band listening to the drums, following the flow of an animated speaker, or selling on stormy waters, the temporal attention abilities must be finely tuned. In some instances, however, this capability fails (Zalta et al., 2020). The paradigm incorporates isochronous perceptual streams in the visual or auditory modality and has been designed continuously with a rhythm between one and two hertz (Comstock, Ross, & Balasubramaniam, 2021; Zalta et al., 2020). This frequency range corresponds to the beat's inherent tempo or frequency. Unlike the continuous flux of actions and perceptual events, the movements are coordinated and rhythmic (Leach, Kolokotroni, & Wilson, 2021). Walking, for instance, is intrinsically rhythmic and occurs at a rate of 2Hz29; similarly, spontaneous, automatic motor behaviors such as motor tapping occur at 0.8 to 2.5Hz, and finger tapping occurs at a rate of 1.50 to 2.00 Hertz (Zalta et al., 2020).

Fig. (1) Rhythm in Nature, https://www.pinterest.co.uk/pin/3082157868416716.

The conclusion is that natural phenomena adopt the "tempo" in ways that are compatible with their requirements for growth and development while also inviting the expression of formal aesthetics and appeal values, which is known as harmony. Those "natural image" indications influenced people's ways of thinking by imitating " spiral cycles, formal enrichment without compromising shape, natural proportions, fractal description, and spatial processing," considering that's, as a mine for our thoughts, which is regarded as one of the most significant human achievements, architecture, which must draw its inspiration from nature. Therefore, rhythm is considered a human response to desires because it consistently reflects biological characteristics.

3. RHYTHM IN POETRY

According to references, rhythm, which emphasizes "verbal indications, linguistic chants," and its fundamental aspects of expression on both sides of "reality, the metaphor," bolsters emotion and establishes the text's aesthetic. In literature, rhythm is frequently viewed as a synchronous phenomenon utilized to significant effect in the production of poetry by • Processing the organizational "distances" and regulating "moves" in poem language in various ways.

• Defining the identity "privacy" and emotional influences "levels" in addition to the vocal harmony "degrees" through compatibility "movement and stillness" (Bauer et al., 2021).

Poem rhythm organizes "cadence," also known as "meter indexing," which over time refers to "time-pronunciation tempo," which lends a dynamic character and helps to control the poetic structure through three joints, the first being "poetic meter," which contains the "horizontal axis," the second being rhyme, which is in charge of the "vertical axis." The third is cohesion between intended meanings. Poetic meter governs the alteration of syntax, word order, and the impression of movement by selecting repeated "words or specific audio clips." This is occurring through the use of "verbal anagrams." As for rhythmic effects for rhyme, repetition of "letter, pronunciation" produces a melodic effect, whereas poetic image transitions produce the third effect (Lane et al., 2023). These effects led to the expansion of the aesthetics of linguistic art, and the division of time into tones (number of responses) appears to occur in two ways: • External rhythm focuses on (poem structure) by organizing horizontal and vertical paths and straightening the interactive sections. • Internal rhythm aims to fine-tune sound within the poetic text; it depends on (syntax and pronunciation) and leads to the discovery of a vocal hymn that accepts the poetic sentence (Zalta et al., 2020).

Poetry evokes emotion; Rhythm is one of the essential prosodic signals of the memetic simulation of poetry, which produces specific emotional states (Johnson-Laird & Oatley, 2022). The importance of words and notions in poetry varies. Typically, poets employ rhythms to create the flow of words, which aids the observer in evoking emotion (Butler-Kisber, 2020). According to Panasenko et al., rhythm is the melodic sequence; some of the poetry's notes begin with the same beat, while others occur between moments and beats, making the poem or melody rhythmic (Panasenko, Stashko, & Zabuzhanska, 2023). Music improvisers, composers, writers, and poets can use meters to alter and modify the predictability of the use of syncopations and the notes in the rhythms; and to determine which note occurs before or after a particular beat. The perception of the meter may be contingent on the cadence, and it follows the critical onsets of the events. According to Bishop, rhythms make children's games viable and engaging by requiring one child to make the clapping sound of a well-known beat while the other child must predict the rhythm (Bishop, 2021). Their prototypes classify rhythms into families, demonstrating how each family relates to a specific metric division (Johnson-Laird & Oatley, 2022).

Though each poem is unique, it has the form, rhythm, and sequence of perceived events or objects as a distinct pattern of regularity, "aggregation, diversity, and hierarchy"; consequently, rhythm is absorbed into poetry by emphasizing hidden concepts "exact facts, intended force" for the poetic language, which elicits an emotional response (Comstock et al., 2021). Repetition is used as a continuous technique in poetic cadence without making the text monotonous. It also attempts to incorporate the "temporal-spatial" vocabulary with the author's imagination for the text's aesthetic. The author contributes to the organization "internal, external" and the distinction in "the nature of transitions, levels of influence, and adjusting compatibility" through verbal and temporal distances to emphasize the reinforcement of subjective aspects through emotional tendencies, symbolic meanings, etc."

4. RHYTHM IN MUSIC

The music consists of harmonic tones from "periods" of frequencies exhibiting "regularity, union, and proportionality similar to mathematical rules." The organization of the relationship between forms and spaces is facilitated by musical rhythm, which contributes to the perception of harmony.

Rhythms are physically evident in music; they are the varying patterns of note duration (Milne & Herff, 2020). Music contains important auditory information audible on multiple time scales and rates (Musacchia & Khalil, 2020) — cortical activity in music domains to entrain rhythm and secure phase. Within a single musical composition, tempos, rhythms, and dynamics frequently change (Harding et al., 2019). It is impossible to sing a song without rhythm because rhythms are correlated to prosodic characteristics (Harding et al., 2019). According to Nave et al., rhythm evokes specific regular patterns in the listener; however, this depends on the listener's awareness and focus (Nave, Hannon, & Snyder, 2022).

The rhythmic content of "the melody" for musical structure consists of the iteration and succession of "individual units" known as the "motive," which is a "structural unit" for the musical text. As for "theme," it is the result of aggregating several motives "12 to 12 tones" at the onset of melody appearance, whereas "the phrase" consists of an assembly of themes based on manipulating the set "motives" via the rhythmic formulas of work system via: - • Motion control system... via "movement, bridging, mating, feedback, motion feed, and digression," via transformations "variegated and contrasting" for repetition.

• Intermittent continuity... by "breaks, joints, momentary reversal of movement on the long tone" down to rhythmic exhilaration when the stimulus is addressed by "the gesture" and "movement."

Rhythm is generally characterized by harmony due to the golden ratio of music; it results from the repetition of "elements/shape-periods/spaces" and the nature of a "kinetic system, continuity."

5. RHYTHM IN ARCHITECTURE

Repetition is one of the fundamental "laws of unity" in the arts and architecture, along with centralization, proportionality, balance, etc., that contributes to the creation of rhythm; It consists of a constant or variable "alternately" collection of "elements-joints" related to the harmony. For instance, when one side of a piece of glass is designed, the other side must be harmonious in balancing details, materials, dimensions, and continuity of lines to ensure compatibility between building surfaces. Therefore, the various functions for "the architectural components" such as mass, void, surface, element, and details on the horizontal or vertical

dimensions must be applied to one or more rhythmic patterns to maintain the visual forces' equilibrium. This phenomenon occurs by placing identical elements on axes or "elements" with dissimilar spaces on one axis. Rhythms are vital architectural elements that produce a specific architectural atmosphere (Van Ellen et al., 2021). When certain elements tend to recur in a work or task, whether architecture, painting, poetry, music, or any other form of art, the audience experiences a sense of cadence or movement.

To enhance the building's aesthetic appeal, the architect typically employs motifs and unifying rhythms on the exterior and interior (Seppälä, 2021). In architecture, rhythm refers to the repetition of elements like colors, forms, shapes, and lines and unstructured movement in time and space (Khayif, 2021). In many architectural compositions, rhythm is sought. Repetition or reoccurrence of elements in cadence, whether in music or architecture, is a basic compositional principle that gives the object a sense of cohesion. The repetition in architecture could be categorized as strictly dynamic, quasi-temporal, static, or spatial (Moravec, 2019; Sills, 2022; Thapa, 2017). The repetition or rhythm in a building is typically a more purely particular form employed by the architect to convey an association of equilibrium or symmetrical relationship. In the style of a building, for instance, one side of the building mirrors the other, which gives it an immediately understandable manner. In the building or architecture, symmetrical equilibrium must be constructed in a balanced form. According to Lee-Niinioja, repetition is the repetition or continuity of elements such as colors, forms, lines, and geometrical shapes (Lee-Niinioja, 2022). Gradation or gradients are a technique for achieving rhythm (Hasan, Hasan, & Alsubaie, 2021) that involves the progression of colors and conditions.

In general, this act pertains to the nature of rhythm, which is categorized as follows: - • Craft rhythm, which is "monotonous" and devoid of exhilaration, follows a linear approach and produces "stereotypes."

• Architecture rhythm, which depends on rhythmic repetition "varied, opposite," which displays levels of "details, elements, surfaces, joints, group, spaces" on the horizontal and vertical axes or combining between them, has various regulatory principles in composition and measurement, and enhances functions "affirmation, arousing expectations, the harmony of meaning, add colorings to text" (Leach et al., 2021).

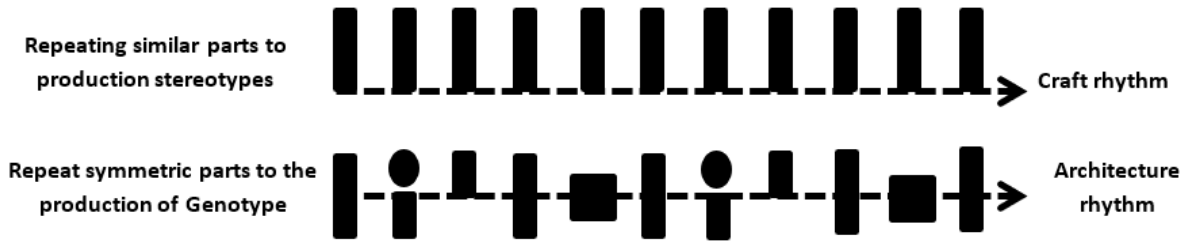

Fig. (2) Rhythm in Architecture (source: researcher).

Repetition is divided into a solely spatial "static form" that employs similarity between elements and relationships along the principal axes and a "dynamic form" that relies on symmetry for "balanced elements," "temporal-spatial" derivations, and metaphor. In addition to several relationships that approximate contemporary architectural concepts (Johnson-Laird & Oatley, 2022), there are ten. Repetition manifests differently in dynamic forms as opposed to static forms because altering time-related "joints, relationships, and levels" introduces a variety of undefined possibilities. It can be accomplished through numerous types of repetition, including:-

• Sequential recurrence of elements, shapes, lines, forms, and colors with distinct characteristics from the preceding phase.

• Progression, associated with a sequence and systematic transition, includes an increase or decrease in one or more characteristics; "systematic change."

• Radiation, the arrangement of elements or spaces around a central point, such as a spiral, creates a radial effect.

• Gradation refers to the transformation "evolution" of forms and colors through an accelerated, abrupt transition or deliberate positioning of them to raise issues, generate oppositions, and heighten aesthetic values that attract the public's attention.

• The term "contrast" refers to the use of a difference in apparent form or context in conjunction with a similarity in meaning. This contrast may be appealing and aid in elucidating new meaning (Butler-Kisber, 2020).

Architecture knowledge and its historical development and cadence have become evident; this has led to the development of architectural structures as aesthetic entities, leading to the automatic control of archaeological values in the present day. In this regard, it is essential to study and consider "Egyptian Architecture," which established large burial chambers "landmarks" in the form of the "Giza-Khufu" "pyramid" and underground tombs in "Valley of the Desolate Kings" in Luxor. Imhotep, the most significant ancient Egyptian architect, designed these structures based on a progressive rhythmic pattern with symmetrical balancing on all sides. Layers of stone "platforms" called "mastabas" produce rhythm. They were constructed from limestone blocks stacked on top of one another, with each level smaller than the one below it (a repetition of the same structure but with little dimension). The layers rise to the point of a triangle, representing "ancient men's belief" to approach the realm of God (Panasenko et al., 2023).

5.1 Literature review

Architecture incorporating rhythm was displayed in different eras of human civilization worldwide, such as the pyramids in Egypt, the Parthenon in Greece, and the Taj Mahal in India. Since the sense of beauty is formed through cultural experience, rhythm is frequently desirable in architectural compositions (Munch, 2021).

The most significant finding is that the arrangement and rhythm of the fractals in traditional houses are most similar to the nature of the fractal structure because they are more dynamic than static. Activity and adaptability will not cause the structure as a whole to descend into chaos (Bishop, 2021).

The study described how random coagulation could generate rhythm in architecture. As a possible mathematical model for the coagulation in the design process, it investigated how the choice of probability for each stage of the coagulation process and the number of stages of the coagulation procedure influence the properties of the obtained fractal objects. It was concluded that random tinkering could be used as a design tool when the values of an architectural element's visual attributes are not rigorously constrained by different requirements and constraints (Milne & Herff, 2020).

The research investigated the fundamental principles and vocabulary that rhythm emphasizes in the design of traditional facades, as represented by unity, gradation, and contradiction (Musacchia & Khalil, 2020).

The literature review did not look at the application of rhythm in the design process, so the research problem was defined as: "The lack of a comprehensive understanding of the origins and applications of rhythm as an accepted phenomenon in architectural design."

A method of exploratory analysis was adopted for the vocabulary that achieves the application of rhythm as an accepted phenomenon in architectural design, as well as the development of an appropriate measure to achieve this vocabulary (rhythm types in architectural design, their antecedents, and their trends).

• Definition of cadence in nature, poetry, music, and architecture

• Access to m deriving conclusions results

5.2 The conceptual difference between rhythm and pattern

The pattern refers to "mentally-materially" accepted ideas that can encapsulate design concepts and serve as archetypal, reusable descriptions, such as "tailor templates" that can be applied to any fabric, whether printed or plain. The pattern provides solutions to assist in the design of "buildings and cities"; thus, the purpose of "typical patterns" is to teach designers how to think and find the solution core of "context, typical class"; therefore, it is a designing language that is borrowed and combined with designer vocabulary "functional, building services, contextual, etc." (Harding et al., 2019). Patterns Inspire the correct concepts without requiring trial and error. It conforms to the human standards deemed suitable for the model's objectives. Based on this, the pattern provides a road map for recurring problems; it has provided us with "values that guide the designer toward the best decision, direct copying, mental representation of the ideas" and has organized relationships between "mass-void, nodes, axles, surfaces, texture, element distribution." If unresolved "conflicting forces" exist in the pattern forces, providing different patterns or developmental phases that may be required to balance vital points is obligatory. For instance, it is the conflict between wanting a room to be light in the winter and cool in the summer. The patterns do not inform designers of the number of windows in a room; instead, they provide a range of application values (cost, materials, etc.) to assist in their decision-making and explain applicability in a broad yet precise manner (Nave et al., 2022). Pattern, according to Soegaard, combines repetitive elements, whereas rhythm is the use of spaces and pauses between the details, which gives the impression of movement or rhythm (Soegaard, 2021).

The pattern is simply the repetition of combining multiple designs or elements that complement one another (Carmi, 2020). A seamless pattern, for instance, is a variety of pattern designs in which each element is combined to form a complete design regardless of how many times it is repeated. Typically, this design serves as the web page's background.

In the rhythm, the repetition of elements conveys a sense of movement or flow to the spectator (Rutrecht et al., 2021). These pauses aid musicians and poets in performing these notes. To create a rhythm, designers may also provide spacing between elements (Awuku et al., 2021).

Pattern offers concealed layers or a theoretical foundation for the application; it helps embody the objectivity vocabulary "architecture" and subjective considerations of "Repeating pattern"

according to the system that generates grid tissue from the module. This procedure causes a "rhythm" representing a concept based on the assembly-type relationships and overarching pattern. Using bricks as an "assembling pattern" to encase facades, for instance, will generate the rhythmic pattern "timed movement" based on the proposed design concept (Van Ellen et al., 2021), which refers to the deliberate sequence as a method of measured movement. Therefore, for the designer, self-performance is the art of harnessing patterns in the timing of events, such as noises, silences, and dance steps. Consequently, recurrence can be divided into three categories: -

• Contrast: There are multiple ideas, "the main, secondary," when one or more patterns are repeated, such as "surface, detail, texture, method of composition," which leads to adding additional properties to the primary idea of repetition.

• Diversity: This is referred to as "Tonal coloring," It depends on displaying the pattern possibilities according to the various movements of content, substance, and form; therefore, the rhythm is based on diversity with "accompanying rules and recruitment method."

• Monotony: The repetition of a pattern or a single idea that imparts a characteristic to horizontal or vertical surfaces to emphasize a technical or functional aspect of the mass (Seppälä, 2021).

Fig. (3) Kind of Rhythm, (source: https://www.lopochina.com).

Designers use groups and spacers in a balanced manner to convey ideas because "number, type, and methods of grouping" for patterns can give the viewer a different sense of rhythm.

5.3 Phenomena and Definition of Rhythm in Design

It emphasizes design meanings by repeating and manipulating production procedures, beginning with one or more of the categories "point, line, surface, shape, shape and color, light and shadow," which are considered Instruments for rhythmic action after employing them to produce different levels of architectural pattern; consequently, the designer can create a model that exemplifies the "visually" harmonious composition.

Former rhythm in a design is the harmonious or regular repetition of a specific element, typically a single entity from sound, shadow, light, color, form, shape, or line (Abad, Tamizi, & Kaboli, 2019; Parashar, 2021). The designer assertively places the elements or categories to generate a pattern or motif. The designer could create rhythm using a particular design composed of element motifs or elements.

This designer repeats the same element until an aesthetically pleasing design is produced. Moreover, the composite composition of these entities spanning multiple categories may also serve the same functions (Soegaard, 2021). The rhythm will not form if the experience of the auditory or visual results is not comfortable and alluring due to the repetition of the elements (Soegaard, 2021).

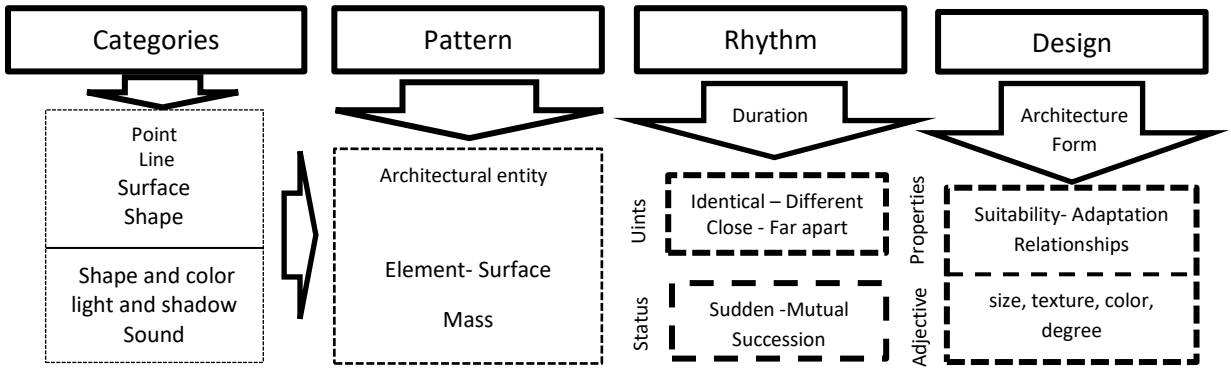

Fig. (4) Pattern and Rhythm in Architecture (source: researcher).

The concept of rhythm is borrowed to circulate in human life applications through continuous frequencies "waves" that are dynamic; it pertains to regular movement according to the suggested system "announced or unannounced" in design; therefore, it gathers between unity and change in product. Consequently, despite the distinctions between sensory and non-sensory dimensions (Sills, 2022), this oscillation harmonizes rhythmic phenomena.

The design must be characterized by suitability and adaptation to attain the desired effect in three-dimensional space. Its elements, including size, texture, color, gradients, and "part-to-whole" ratio, must be organized to prevent separation. Frequency creates identical or distinct units, close or far apart; the distance between each base and another is referred to as "Duration"; in this case, the rhythm is achieved by combining two ingredients; "Units" are positive, and "Timeouts" are negative; under this regulation, the rhythm takes one of two directions (Moravec, 2019).

• Monotonic rhythm... similar repeating on the vertical and horizontal axis, "perfect matching," for each unit and duration in "shape, size, details" on the surface that represents "plans, elevations," but distinct in physical coordinates and perspective visions.

• Unorganized rhythm...similar units or durations, the difference in moving between levels or on the principal axes, manifests in particular characteristics "view scales, proportions."

• Free rhythm...random distribution, various "units, durations," this form of rhythm is governed by a complex or hidden system of relationships; it achieves a variety of perspective visions based on the angles.

• Contradictory rhythm... "units, durations" repeated continuously with decrease or increase, "it is meaning of repetition according to random mathematical sequence - special equations."

• Increased cadence... indicates that the "units - durations" continuously increase following the "scalar sequence" of mathematics. Occasionally, the designer employs multiple design rhythms to accomplish a different impression from the familiar context or to confirm new meanings that reflect civilizational, cultural, and technical values (Thapa, 2017).

5.4 Rhythm in Architecture Movement

The intellectual currents of architecture have differed in rhythm formulas, as "modern architecture" was deliberately neglecting rhythmic formulas of spatial diversity during processing "environmental

problems and functional needs for reasons related to "machine" manufacturing techniques, resulting in the adoption of stereotypes with continuous and repetitive features "formal, informal, radial, vertical, horizontal," on all or part levels, which led to regular rhyming patterns.

The deliberate positioning of elements and abrupt transitions add aesthetic value to the rhythmic design and heighten the audience's interest (Kim et al., 2019; Kim & Lazar, 2020). Using different elements on various axes and placing the same elements on identical axes, the designer or architect gives the designs a balanced and comfortable visual appearance (Gottlieb et al., 2019). For instance, one of the most notable examples of the progressive rhythmic pattern in architecture is the world-famous pyramids of Egypt, which are symmetrically balanced from top to bottom.

The postmodern methodology has employed technology in addition to the linguistics of spatial expression as a site for coordinates, leading to the harmony of the traditional performance between "material & immaterial" as a biological cadence. Thus, rhythm is directed toward "gradation, contradiction, increase, and decrease," emphasizing the values of qualitative representations of the outputs. This means that the impression of the sensory image tends toward simplicity, diversity, and renewal, thereby emerging as one of the modern tendencies.

In the meantime, contemporary movements, such as deconstruction, have sought the origins of "architectural & non-architectural" genres, seeking new approaches or re-adapting old systems that can be evaluated and chosen. This contributed, on the one hand, to the discovery of unfamiliar visual perceptions and, on the other, to the emergence of new, ambiguous meanings susceptible to multiple interpretations. Consequently, rhythm adopted a different path, such as randomness within the concealed system. This effort expanded horizons beyond the limits of Euclidean geometry (Hasan et al., 2021).

5.5 Factors causing rhythm in architecture

Repetition is the driving force behind rhythm; it prepares a rhetorical instrument that helps us find a cognitive way of processing information by emphasizing a point, line, concept, or meaning in numerous ways. Thus, rhythm pertains to the quality concerning the choices-justifications, levels of repetition, and the impression of how perceivers observe the results after automatic repetition, which can create order throughout the entire design.

This established order defines rhythmic phenomena. It led to the establishment of levels of regularity, simplicity, and compositional balance, enabling the design to develop a natural relationship between the design concept and the consistency of elements, ideas, and context artwork. This comprehension and harmony will facilitate the view. After recognizing the rhythmic pattern, it was possible to perceive the entire design. Understanding similar movement and transformation rules would generate an ordered way that draws the viewer's visual attention to assimilate cognitive processes while investigating the pattern's semantic context (Soegaard, 2021).

Harmony is the most essential principle of construction and architecture because it balances the building's height, width, and length. Repetition of the design and specific elements is crucial (Ford, 2023). It is necessary to maintain equilibrium or symmetry in creating a building to ensure that all sides are identical and symmetrical. For example, if a shape design or glass appears on one side, it must also appear on the opposite side. In architecture, repetition manifests differently in its static variant form than in its dynamic form because, with the passage of time and the emergence of new fashions, countless inconceivable possibilities have

been introduced (Conforti, 2019). rhythm in architecture relates to the transition or sequence produced by decreasing or increasing one or more qualities; progression is ordered systematically. For instance, a radical impression is created when spaces or elements are arranged around a central point, such as in a spiral (Harjo, 2019).

5.6 Phenomenology of Rhythm in architecture design

In addition to techniques supported by architectural movements, architecture employs means from natural phenomena for expressiveness' sake. This is achieved through production procedures such as metaphor, copy, and imitation, embodied in the rhythmic grids composed of "points, elements, nodes, and surfaces." This means that all scientific hypotheses, laws, and philosophical views seek formulas and definitions that express the rhythmic beating in the space, which is determined by many factors: - 1- Rhythmic alternation: accomplished by a series of repeating "motifs & elements," presented in a variety of formulas; (thick/thin, short/long, dark/light, round/square), a condition that maintains the rotational continuity when viewed. It encompasses, in a broader sense, all the expressive variations of the rhythms and tempos (Conforti, 2019).

2- Rhythmic gradation: it is used to relate images one to another by the entire scene through a regular progression or transitional morphology such as "chromatic, scales, and textures"; these lead to a hierarchy and series of successive events (Carmi, 2020). It employs a sense of progression that guides the eye from one end of the space to the other (Dzamukashvili, 2021). This principle can transform the color and scale of the same object from dark to light or from large to small. The staircase is one of the best examples of gradation because it allows for the smooth movement of the eye between various floor levels.

3- Rhythmic emphasis refers to "contact & disconnection" for the fundamental pattern or aggregation formulas and movement that strongly confirms locations by dividing configuration into a primary and secondary emphasis point, emphasizing the secondary sections of the composition. Color, numerals, layers, and background can accomplish this objective. It typically interrupts the viewer's eye's fundamental movement or pattern by breaking or composing a rhythm (Mansoor et al., 2021). Architects, designers, and artists employ rhythmic emphasis to draw attention to a particular object or element or to distinguish the composition by providing visual surprises to maintain the viewer's interest.

4- Rhythmic contrast: determined by "point, surface, and mass" regardless of the scene's context. Contradictions can exist on a two-dimensional or three-dimensional level through "color, texture, shape, or scale," as well as on a sensory level through "light-shadow" and spatial relationships (Rutrecht et al., 2021). In architecture, the contrast in rhythms of designs is the repetition and recurrence of forms, shapes, lines, or colors in time and space (Van Ellen et al., 2021).

5- Rhythmic placement: it refers to the strategic position, that is, the location of the element that agrees but differs from the context, and it emphasizes the signal substantially. It is the style of rhythms or how patterns are formed, and parts are arranged to create a particular design (Walker, 2021).

6- Rhythmic unity refers to the coherence of all parts through "horizontal & vertical elements unit, parts proportions, and joints between surfaces" (Awuku et al., 2021). This refers to the harmony of the entire design or structure. The rhythmic unity is the coherence of the whole design, which gives all the elements and components working together to accomplish a common goal (Hosny Abd Elhafez Eldeeb, 2021) meaning.

Fig. (5) Phenomenology of rhythm in architecture design, (Lee-Niinioja, 2022; Thapa, 2017).

5.7 Rhythm features in architectural design

Contemporary geometrical shapes are characterized by Influential motion, which has multiple manifestations when classified as "identical, straight, curved, and sloping." The motion is given multiple orientations by manipulating motifs, items, and patterns with "qualitative-quantitative" repetition, physical transformations of the shape, shifting levels, and spatial and temporal displacement. These interventions affect design principles by their responsibility for generating rhythmic patterns regardless of "size, shape, texture, and color," which means that altering the shape or size does not affect the expression (Parashar, 2021).

Rhythmic manifestation occurs due to rhythmic procedures and regular combinations of architectural elements. Organizing these organizations involves: - • The rhythm of lines: horizontal or vertical elements (such as columns) of various sizes, it distinguishes the principal or secondary corridors and entrances or adopts methods to divide the surfaces of the blocks "finishing materials" into units: regular – irregular.

• The cadence of levels: horizontal or vertical surfaces that assume various forms (e.g., "circular, curved"). With regular or flowing scales, it takes multiple relationships, such as "over layers, juxtapositions, and intersections" in building facades such as monument buildings, depending on whether the location is "symbolic or functional or another consideration."

• The rhythm of masses: Architectural formations must be explained as symmetrical forms, such as "mosque domes" According to successive proportions based on functional or symbolic data relating to relationships, such as "parallel, interlaced, horizontal & vertical," masses exhibit "similarity, contrasting symmetry."

• The rhythm of the curve: horizontal or vertical curves, designed on levels, which means sculpting mass and space through architectural and structural components, by "site, elements, surfaces, and decorations" as in organic architecture.

• Oblique rhythm: directionality in oblique details, elements, forms, and formations in horizontal plans or interfaces. In addition to the inclusion of secondary and escalator ladders (Abad et al., 2019), additional features will be added.

Fig. (6) Rhythm features in architectural design, (Hasan et al., 2021; Soegaard, 2021).

5.8 Rules of creating rhythm in architecture design

The rules that can define the rhythm pass through a series of operations on rhythmic units; they depend on "permanent patterns" that can dominate the dominant scene and emphasize specific goals that are classified according to the character of the mass-space relationships. For instance, "functional nodes, masses-defining surfaces, axis uses, framing poles, portals, openings, brackets, and domes." There are also superficial effects that concur with patterns and strengthen ideas; they function as a backdrop to highlight another type of rhythm; they are known as transferring effects "fixed or variable" on surfaces, such as "color difference, tonality, shade, and light, interior - exterior finishing, materials, texture, and details" (Kim et al., 2019).

Rhythm is typically employed in building design to describe the mental effort required to create a repetitive arrangement and the nature of the result. It seeks to achieve the sequential organization of spatial, functional, symbolic, and technical considerations that reflect development on the design or executive level. As a result, it offers an infinite number of new meanings and suggestions that improve the relationship between the natural world and human-made lifestyles, but in a new way that c (Kim & Lazar, 2020).

As shown in Table 1, the vocabulary of the primary and secondary theoretical frameworks and potential values can be crystallized as it was extracted from the knowledge framework and prior literature.

Table 1. The primary & secondary vocabulary of the theoretical framework (source: researcher)

Main Vocabulary		Secondary Vocabulary & Possible Values	Symbol
Rhythm in Architecture	Rhythm typesssssss in architectural design X.1	The rhythm of the lines	X.1.1
		The rhythm of levels	X.1.2
		The rhythm of masses	X.1.3
		The rhythm of the curve	X.1.4
		The rhythm of oblique	X.1.5
	Rhythm determinants in architectural design X.2	Rhythmic alternation	X.2.1
		Rhythmic gradation	X.2.2
		Rhythmic emphasis	X.2.3
		Rhythmic contrast	X.2.4
		Rhythmic placement	X.2.5
		Rhythmic unity	X.2.6
	Rhythmic Directions in architectural design X.3	Monotonous rhythm	X.3.1
		Unorganized rhythm	X.3.2
		Free rhythm	X.3.3
		Contradictory rhythm	X.3.4
		Increased rhythm	X.3.5

The practical study requires submitting to a qualitative measurement, where all the vocabularies of the phenomenon of rhythm in architecture will be measured in the selected projects, depending on the symbol (1) to indicate verification and symbol (0) for non-verification, as shown in Table (2) and Fig. (10)

6. APPLICATIONS

6.1 Application to samples

To test the research hypothesis stated as follows: "The rhythm influences the designer by directing him toward specific directions, determinants, or types in architecture," the selection criteria for the projects included the following elements:

• The selected projects belong to distinct spatial contexts and have the required information and plans for their description and analysis. Thus, the intended outcomes of the research will be improved.

• The selected projects are from different eras to clarify the permanence of rhythm's influence on them, as the design of each project relied on specific rhythmic types and trends proportional to the period.

• This also applies to instrumental training, as rhythm is an essential element of musical training and classes. All music-related training programs include a variety of cadence and pitch-related components. The synchronization of at least two independent rhythmic processes constitutes entertainment. For instance, in music, the sound of tapping or clapping creates a distinct rhythm, which requires sensory motor integration coordination of movement and auditory perception of the rhythm (Harding et al., 2019). Individuals engaged in musical training and musicians performing collectively can achieve natural synchronization with rhythm.

6.1.1 Parthenon in Athens, 5th c. B.C.

At the time of the ancient Greeks, the Parthenon was a significant architectural structure designed with a regular cadence. It is a "peripheral Doric octastyle temple" with Ionic architectural elements. It stands on a three-step platform. The Greeks utilized repetition of forms for the columns and repetition of dimensions for the space between the columns. In addition, the top of this building's front facade features a repeat of differences, as it goes from small to large to tiny again. The Parthenon was designed with a regular rhythm by arranging parallel columns and rows with fixed distances between them.

Nonetheless, the variety was expressed through "layers, volumes, lighting, and proportions," which resulted in a standardized system that enhanced the aesthetic and functional character of the structure. The golden ratio is present in the Parthenon's dimensions, which are 30,8 meters wide and 69,51 meters long. This constitutes a 4:9 ratio. This proportion is also evident in the width of the Parthenon's front columns and the height-to-width ratio of the building's facade. As shown in Fig. (7), although the proportion of 9:4 is the most visible within the Parthenon, the balance of 3:2 is the key to its proportioning (Gottlieb et al., 2019).

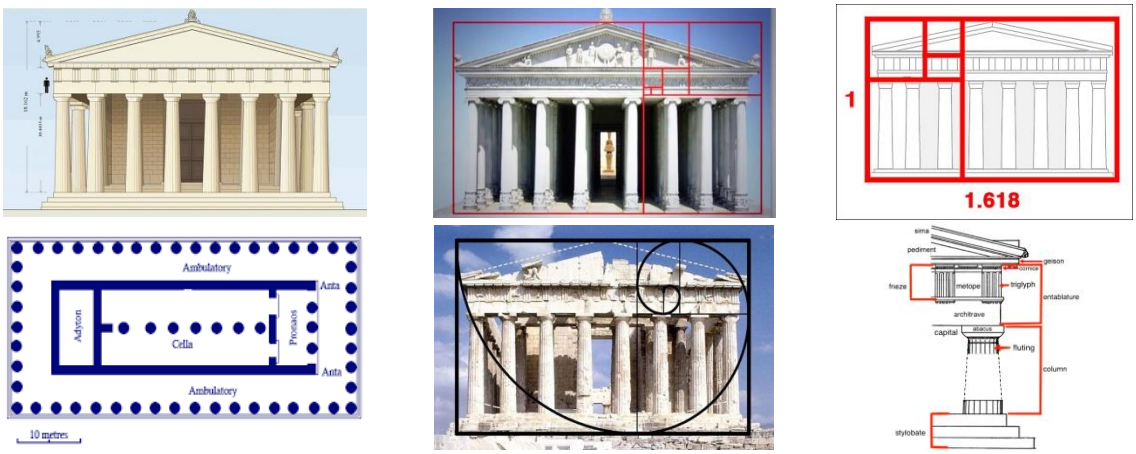

Fig. (7) Greek architectural orders (source: https://www.baianat.com/ar/books/grid-system-and-its-effective-role-in-design/golden-ratio

6.1.2 Swiss Pavilion in Paris, 1930

The International University Campus in Paris (CIUP) is an architectural complex renowned for the character and variety of its buildings, situated in a 34-hectare landscaped park. Le Corbusier was selected to design the pavilion. Le Corbusier devised the Modular system for the Swiss pavilion, an anthropometric scale of proportions based on the human body and the golden ratio. The architectural specification was kept to a bare minimum: forty-two student rooms, a lounge area, an entrance hall, an office, and an apartment for the director. Despite the small dimensions (2,8 x 6 meters), the design's strength rests in the rooms' rhythmic symmetry. Le Corbusier and Pierre Jeannette developed a manifesto for contemporary architecture based on five rhythmically harmonious levels: "pillars, the roof garden, free design of the ground plan, the horizontal window, and free facade design" – of which the Swiss Pavilion is a superb example. The Swiss Pavilion's design is founded on "REGULAR RHYTHM." It refers to a piece of art that consists of recurrent elements in a measurable order or arrangement. Examples of regular rhythm include evenly spaced windows and tiles (Ford, 2023), as depicted in Fig.

Fig. (8) Swiss Pavilion in Paris, (source: https://www.archdaily.com/358312/ad-classics-swiss-pavilion-le-corbusier

6.1.3 Riyadh metro in Saudi Arabia, 2018

The new station, the King Abdullah Financial District Metro Station, will be a significant hub for Riyadh's 5 million residents. The main element of the station is its three-dimensional webbed steel skeleton defined by a sequence of opposing sine waves (generated from the repetition and frequency variation of the station's daily traffic flows), which acts as the spine for the building's circulation. These sine waves are extended to the station's envelope and strictly affiliated with its internal layout, translating the architectural concept to the exterior by rhythmically harmonious style. While the metro station's façade features a unique pattern that reduces solar gain, the overall composition resembles patterns of desert winds in dunes, where multiple frequencies and repetition generate complex natural formations. According to Circular harmonious rhythms, the interiors show characteristic curves and significant double volumes. Finally, the new building will have six platforms over four public floors and two levels of underground car parking. The station will have more than 20,000 square feet of space (Harjo, 2019), as shown in Fig (9).

Fig. (9) Riyadh metro in Saudi Arabia, (Abad et al., 2019).

6.2 Analyzing and discussing the results

This paragraph describes the most significant indications of the application's results on the selected samples:

• The results of (rhythm type in architectural design- X.1) are as follows: The indicators (X.1.1-X.1.3) were achieved (100%) in the projects, and the percentage of verification of indicator (X.1.2) decreased to (67%) in projects (A, & C), in addition to the decrease in the ratio of indicator (X.1.4) to (33%). In contrast, the indicator (X.1.5) did not exist.

• The results of (rhythm determinants in architectural design - X.2) are as follows: The indicators (X.2.1-X.2.6) were achieved (100%) in the projects, the percentage of verification of indicator (X.2.2) decreased to (67%) in projects, and the ratio of indicators (X.2.3-X.2.4) decreased to (33%), but indicator (X.2.5) did not exist.

• The outcomes of (rhythmic directions in architectural design- X.3) are: The ratio is (31%), the indicator (X.3.3) was attained with a percentage of (100%) in the projects, and the ratio of verification of the three indicators (X.3.1-X.3.4-X.3.5) decreased to (33%), while the existence of the indicator (X.3.2) was not verified, as shown in Table (2) and Figure (10).

Table 2. Project analysis (A, B, C).

Symbol	X.1.1	X.1.2	X.1.3	X.1.4	X.1.5	X.2.1	X.2.2	X.2.3	X.2.4	X.2.5	X.2.6	X.3.1	X.3.2	X.3.3	X.3.4	X.3.5
A	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**
B	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	0	**0**
C	1	1	1	**1**	0	**1**	1	**1**	1	**0**	**1**	0	0	**1**	0	1
Total	3	2	3	1	0	3	2	1	1	0	3	1	0	3	1	1
percentage	%100	%67	%100	%33	%0	%100	%67	%33	%33	%0	%100	%33	%0	%100	%33	%33

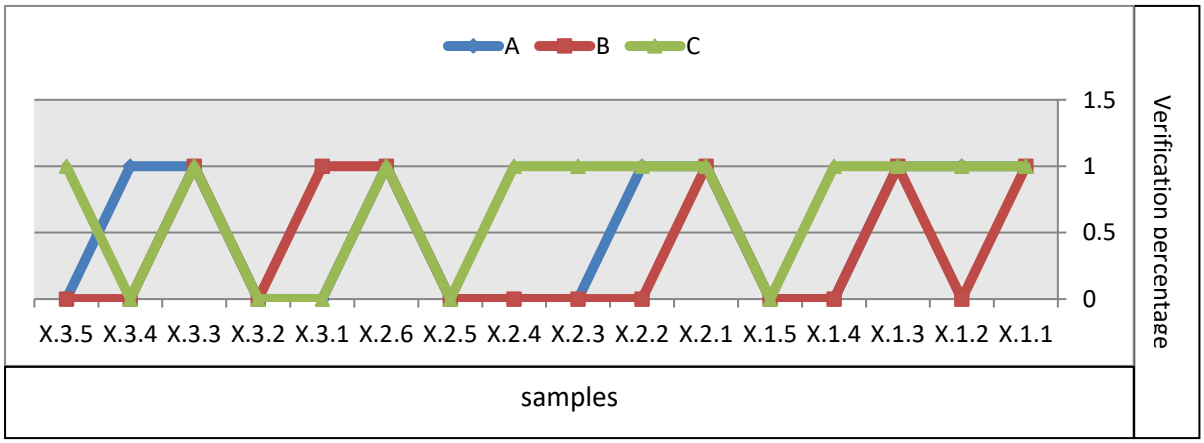

Fig. 10. The percentages of the vocabulary verification of the theoretical framework in the elected projects (source: researcher).

7. CONCLUSION

This paragraph discusses the most significant findings from the theoretical and practical perspectives, which are as follows:

In architecture, rhythm refers to repeating elements such as lines, shapes, or hues that produce an organized movement in space and time. Rhythm is founded on five principles: repetition, gradation, transition, contrast, and radiation. Frequently, designers will repeat specific project elements in a patterned flow throughout the architectural output, which can create a sense of movement and guide viewers through the component in a predetermined pattern. Rhythms aid architects and designers in producing identical and symmetrical building designs and patterns.

To accomplish rhythmic unity, the application results revealed that architects favored "rhythmic alternation, rhythmic gradation, and rhythmic contrast" over "monotonous and disorganized rhythm." Architecture accomplishes rhythm through repetition, which generates a specific rhythmic system that contributes to the aesthetic of the finished product. Movement and cadence are created by repeating elements in a regular, random, alternating, flowing, or progressive pattern.

RECOMMENDATIONS

- The research recommends studying the possibility of the effect of rhythm in creating architectural output
- The research recommends studying the prevailing rhythm in local architecture
- Studying the rhythm in light of the technical progress and the speed of changes witnessed by the architectural movements

FUTURE RESEARCH PROSPECTS

- Exploring the effect of rhythm on the perception of the aesthetics of architecture
- Determine the aspects of rhythm in the relationship between the design process and the architectural style
- The study recommends that future researchers analyze the impact of technological uses and advancements of rhythm in architecture.
- This research suggests exploring the impact of rhythm in building on sustainability and the environment.

REFERENCES

Abad, S., Tamizi, M., & Kaboli, A. (2019). Towards a New Perspective for Designing Form Based on Music. *Specialty Journal of Humanities and Cultural Science*, *4*(4), 24-36. https://sciarena.com/article/towards-a-new-perspective-for-designing-form-based-on-music

Awuku, S. A., Bennadji, A., Muhammad-Sukki, F., & Sellami, N. (2021). Myth or gold? The power of aesthetics in the adoption of building integrated photovoltaics (BIPVs). *Energy Nexus*, *4*, 100021. https://doi.org/10.1016/j.nexus.2021.100021

Bauer, A.-K. R., Van Ede, F., Quinn, A. J., & Nobre, A. C. (2021). Rhythmic modulation of visual perception by continuous rhythmic auditory stimulation. *Journal of Neuroscience*, *41*(33), 7065-7075. https://doi.org/10.1523/JNEUROSCI.2980-20.2021

Bishop, J. (2021). The performers in the playground: Children's musical practices in play. In *The Routledge Companion to English Folk Performance* (pp. 550-584). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9780429299063-26

Butler-Kisber, L. (2020). Poetic inquiry. In *Poetry, Method and Education Research* (pp. 21-40). Routledge. https://doi.org/10.4324/9780429202117-3

Carmi, E. (2020). Rhythmedia: A study of Facebook immune system. *Theory, culture & society, 37*(5), 119-138. https://doi.org/10.1177/0263276420917466

Comstock, D. C., Ross, J. M., & Balasubramaniam, R. (2021). Modality-specific frequency band activity during neural entrainment to auditory and visual rhythms. *European Journal of Neuroscience*, *54*(2), 4649-4669. https://doi.org/10.1111/ejn.15314

Conforti, M. (2019). *Field, Form and Fate: Patterns in Mind, Nature, & Psyche*. Fisher King Press. https://fisherkingpress.com/n/product/field-form-and-fate

Dzamukashvili, N. (2021). For rhythmic pattern of the ebony tower by John fowles. *Conferencious Online*, 48-52. http://www.conferencious.com/index.php/conferences/article/view/62

Ford, D. R. (2023). Arrhythmanalysis and Revolutionary Rupture of Détournement: Lefebvre and the Pedagogical Rhythms of Post-Fordism. *Postdigital Science and Education*, *5*(2), 440-454. https://doi.org/10.1007/s42438-021-00285-x

Gottlieb, E., Landau, E., Baxter, H., Werden, E., Howard, M. E., & Brodtmann, A. (2019). The bidirectional impact of sleep and circadian rhythm dysfunction in human ischaemic stroke: a systematic review. *Sleep Medicine Reviews*, *45*, 54-69. https://doi.org/10.1016/j.smrv.2019.03.003

Greenbaum, J., & Kyng, M. (2020). Introduction: situated design. In *Design at work* (pp. 1-24). CRC Press. https://doi.org/10.1201/9781003063988-1

Harding, E. E., Sammler, D., Henry, M. J., Large, E. W., & Kotz, S. A. (2019). Cortical tracking of rhythm in music and speech. *Neuroimage*, *185*, 96-101. https://doi.org/10.1016/j.neuroimage.2018.10.037

Harjo, L. (2019). *Spiral to the Stars: Mvskoke Tools of Futurity*. University of Arizona Press. https://uapress.arizona.edu/book/spiral-to-the-stars

Hasan, M. M., Hasan, N., & Alsubaie, M. S. A. (2021). Development of an EEG Controlled Wheelchair Using Color Stimuli: A Machine Learning Based Approach. *Advances in Science, Technology and Engineering Systems Journal*, *6*(2), 754-762. https://dx.doi.org/10.25046/aj060287

Holtzen, S., Dumas, C., Adeyinka, O., Bertels, H., Burton, K., Campbell, A., Chukwuba, K., Grandinetti, M., Gregory, C., Moran, R., Sherman, K., & Tran, H. (2022). The Zoo at North River Veterinary: The Second Generation. *International Journal of Instructional Cases*, *6*. http://www.ijicases.com/search/the-zoo_case

Hosny Abd Elhafez Eldeeb, M. (2021). Possible design solutions in mural painting on the rhythm of contradictions. *International Journal of Design and Fashion Studies*, *4*(2), 133-161. https://dx.doi.org/10.21608/ijdfs.2021.226054

Johnson-Laird, P. N., & Oatley, K. (2022). How poetry evokes emotions. *Acta Psychologica*, *224*, 103506. https://doi.org/10.1016/j.actpsy.2022.103506

Khayif, S. H. (2021). Aesthetics Of Design Elements In The Drawings Of Futuristic Movement Artists. *Elementary Education Online, 20*(5), 7885-7919. http://dx.doi.org/10.17051/ilkonline.2021.05.893

Kim, J.-H., Seo, S.-Y., Song, C.-G., & Kim, K.-S. (2019). Assessment of electrocardiogram rhythms by GoogLeNet deep neural network architecture. *Journal of healthcare engineering, 2019*, 2826901. https://doi.org/10.1155/2019/2826901

Kim, Y. H., & Lazar, M. A. (2020). Transcriptional control of circadian rhythms and metabolism: a matter of time and space. *Endocrine Reviews, 41*(5), 707-732. https://doi.org/10.1210/endrev/bnaa014

Lane, J. M., Qian, J., Mignot, E., Redline, S., Scheer, F. A., & Saxena, R. (2023). Genetics of circadian rhythms and sleep in human health and disease. *Nature Reviews Genetics, 24*(1), 4-20. https://doi.org/10.1038/s41576-022-00519-z

Leach, D., Kolokotroni, Z., & Wilson, A. D. (2021). Perceptual information supports transfer of learning in coordinated rhythmic movement. *Psychological Research, 85*(3), 1167-1182. https://doi.org/10.1007/s00426-020-01308-1

Lee-Niinioja, H. S. (2022). *The Continuity of Pre-Islamic Motifs in Javanese Mosque Ornamentation, Indonesia*. Archaeopress Publishing. https://www.archaeopress.com/Archaeopress/DMS/73AF9E4063DB4A3081564076EF418285/9781803270487-sample.pdf

Mansoor, H., Gerych, W., Alajaji, A., Buquicchio, L., Chandrasekaran, K., Agu, E., & Rundensteiner, E. (2021). ARGUS: Interactive visual analysis of disruptions in smartphone-detected Bio-Behavioral Rhythms. *Visual Informatics, 5*(3), 39-53. https://doi.org/10.1016/j.visinf.2021.07.001

Milne, A. J., & Herff, S. A. (2020). The perceptual relevance of balance, evenness, and entropy in musical rhythms. *Cognition, 203*, 104233. https://doi.org/10.1016/j.cognition.2020.104233

Moravec, M. (2019). Perpetual Present: Henri Bergson and Atemporal Duration. *European Journal for Philosophy of Religion, 11*(3), 197-224. https://doi.org/10.24204/ejpr.v0i0.2629

Munch, A. V. (2021). *The Gesamtkunstwerk in design and architecture: From Bayreuth to Bauhaus*. Aarhus Universitetsforlag. https://unipress.dk/udgivelser/t/the-gesamtkunstwerk-in-design-and-architecture

Musacchia, G., & Khalil, A. (2020). Music and Learning: Does music make you smarter. *Frontiers for Young Minds, 8*, 81. https://doi.org/10.3389/frym.2020.00081

Nave, K. M., Hannon, E. E., & Snyder, J. S. (2022). Steady state-evoked potentials of subjective beat perception in musical rhythms. *Psychophysiology, 59*(2), e13963. https://doi.org/10.1111/psyp.13963

Panasenko, N., Stashko, H., & Zabuzhanska, I. (2023). 73 Love and rhythm in poetry and music. In S. Gesine Lenore, A. Jeanette, & N. Bee Chin (Eds.), *Language and Emotion, Volume 3* (pp. 1529-1557). Berlin, Boston: De Gruyter Mouton. https://doi.org/10.1515/9783110795486-009

Parashar, L. G. (2021). Elements of Art. *ShodhKosh: Journal of Visual and Performing Arts, 2*(1SE), 8–15. https://doi.org/10.29121/shodhkosh.v2.i1SE.2021.15

Rutrecht, H., Wittmann, M., Khoshnoud, S., & Igarzábal, F. A. (2021). Time speeds up during flow states: A study in virtual reality with the video game thumper. *Timing & Time Perception, 9*(4), 353-376. https://doi.org/10.1163/22134468-bja10033

Seppälä, S. (2021). Musical language unlocking sacred spaces: Armenian architecture experienced. In A.-V. Kärjä & S. Korkalainen (Eds.), *Sounds Sanctified: Essays on Music and the Sacred* (pp. 50-77). Suomen Etnomusikologinen Seura. https://jyu.finna.fi/Record/arto.018116623

Shine, J. M., Breakspear, M., Bell, P. T., Ehgoetz Martens, K. A., Shine, R., Koyejo, O., Sporns, O., & Poldrack, R. A. (2019). Human cognition involves the dynamic integration of neural activity and neuromodulatory systems. *Nature neuroscience*, *22*(2), 289-296. https://doi.org/10.1038/s41593-018-0312-0

Sills, H. (2022). *Stravinsky, God, and Time*. Brill. https://doi.org/10.1163/9789004518537

Soegaard, M. (2021). *Repetition, Pattern, and Rhythm*. Interaction Design Foundation. https://www.interaction-design.org/literature/article/repetition-pattern-and-rhythm

Thapa, R. (2017). Rhythm in architecture: An aesthetic appeal. *Journal of the Institute of Engineering, 13*(1), 206-214. https://doi.org/10.3126/jie.v13i1.20368

Van Ellen, L., Bridgens, B., Burford, N., & Heidrich, O. (2021). Rhythmic Buildings-a framework for sustainable adaptable architecture. *Building and Environment*, *203*, 108068. https://doi.org/10.1016/j.buildenv.2021.108068

Walker, G. (2021). *Energy and Rhythm: Rhythmanalysis for a Low Carbon Future*. Rowman & Littlefield. https://rowman.com/ISBN/9781786613363

Zalta, A., Petkoski, S., & Morillon, B. (2020). Natural rhythms of periodic temporal attention. *Nature communications, 11*(1), 1051. https://doi.org/10.1038/s41467-020-14888-8