Scientific and Social Research, 2025, Volume 7, Issue 5
https://ojs.bbwpublisher.com/index.php/SSR
Online ISSN: 2981-9946
Print ISSN: 2661-4332

Research on the Composition Mechanism of the Golden Ratio: Aesthetic Processing of Visual Balance

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Abstract: Does the golden ratio in composition bring about visual balance and aesthetic pleasure? What are its underlying mechanisms? This study explores composition and aesthetic preferences, suggesting that visual balance is dynamic and subjective in nature. The physiological structure of human vision, particularly the dominance of one eye, leads to visual field imbalance during aesthetic appreciation. As a result, the subjective center of balance in an image often aligns with the golden ratio point. The mechanism of aesthetic processing in visual perception contributes to the construction of subjective visual balance, and the visual stimulus generated by golden ratio composition may influence this aesthetic processing. Therefore, the aesthetic processing of visual balance can help explain the mechanism underlying the golden ratio in composition.

Keywords: Golden ratio; Visual balance; Aesthetic processing

Online publication: June 6, 2025

1. Introduction

The aesthetic appeal and universality of the golden ratio have been widely recognized [1–2]. Many artists have also utilized the golden ratio in their compositions [3]. Viewers often perceive a sense of universal beauty in works constructed according to the golden ratio, and this configuration tends to facilitate aesthetic fluency due to its ease of processing [4]. However, the underlying mechanisms of how the golden ratio functions during aesthetic processing remain unclear. To address this gap, the present study aims to explore, investigate, and analyze the mechanisms by which the golden ratio influences aesthetic processing and the nature of the aesthetic experiences it evokes.

2. Composition and aesthetic preference

2.1. Explanation of composition and balance

Composition refers to the organization of the interrelationships among objects and forms; it is central to the creation of works of art and to aesthetics itself, across both visual and other art forms [5]. A classic approach to understanding the essence of composition can be found in Gestalt psychology, with Rudolf Arnheim as a representative figure. Arnheim emphasized the holistic interpretation of an image or space, highlighting the existence of interacting and balancing forces within it. The sense of balance in an image is fundamental to composition.

Arnheim provided two classic explanations regarding compositional balance. On one hand, he proposed that the sense of balance in an image arises from the perceptual forces acting upon objects within a frame; when the various forces acting on an object neutralize each other, the object attains a state of balance. This definition applies to the equilibrium of visual forces as well, with the center of balance positioned where these forces reach equilibrium [6]. On the other hand, Arnheim pointed out that in a square frame, the center of balance is determined primarily by the intersection of its four axes—namely, the center formed by the crossing of the two sets of parallel sides and the diagonals connecting opposite corners [7].

Given these two accounts, is there a contradiction between Arnheim's views?

2.2. Contradictions in the research of Arnheim and his followers

Regarding the first viewpoint, Arnheim believed that under the influence of perceptual forces, one can intuitively identify a center within a geometric space without the need for explicit demarcation [8]. According to perceptual experience, there exists a point in the image where the forces from all directions reach equilibrium—this is referred to as the balance center. Palmer et al. conducted an in-depth study of Arnheim's concept of the "center", finding that the perceived center does not have to be the exact geometric center of the image [9]. Instead, it can vary in shape and location depending on the arrangement of objects and spaces within the scene. The center of a given object, or a group of objects, may also deviate from its precise geometric or center of mass [9]. However, Palmer and colleagues' experiments were conducted under restricted conditions—namely, in frames without other stimuli. In such scenarios, the object itself inevitably attracts visual attention, and its orientation naturally leads to a preference toward the interior of the frame. Consequently, these findings do not fully address the issue of balance within an image.

As for the second viewpoint, Arnheim and his followers argued that symmetrical patterns are inherently the most balanced and tend to elicit preference. For instance, Palmer and Guidi found through their experiments that the intersection of vertical and horizontal axes of symmetry is consistently perceived as the most ideal position [10]. This result aligns with Arnheim's perspective: within a rectangular frame, certain positions are particularly well-suited for object placement. Guidi and Palmer noted that most two-dimensional visual artworks are comprised of elements organized within a rectangular frame. The aesthetic success of such compositions likely depends on the interplay between the frame's internal structure and the arrangement of constituent elements. Arnheim asserted that the structural skeleton provided by the frame acts as scaffolding for the composition, and that elements arranged along this structural skeleton appear more balanced and stable. However, these views and experiments are based on empty frames, where visual perception is not influenced by other stimuli, resulting in relatively simple aesthetic judgments. In reality, aesthetic judgments may also be influenced by personal cognition and sociocultural factors. When there are multiple stimuli within an image, visual attention is not necessarily drawn to the center of the frame.

2.3. Application of Arnheim's theory in painting appreciation

Arnheim argued that the dynamics of forces are equally evident in the appreciation of painting [7]. During visual appreciation, the viewer serves as a dynamic center, scanning the entire composition in order to perceive it as an integrated whole. The viewer then selects a particular point as the focal center, establishing a dominant center around which the elements of the composition achieve overall balance. Arnheim also suggested that the issue of balance can be explained in physical terms: in a state of equilibrium, the various forces acting on an object cancel each other out, and each physical entity possesses a center of gravity or a point of support [7]. Fundamentally, Arnheim's theory of balance is a method of arranging objects within the visual field to achieve visual balance and even elicit aesthetic preference.

Tyler, however, critiqued Arnheim's balance theory as lacking a scientific foundation, arguing that it is based on Gestalt psychologists' theories regarding neural force fields in the primary visual cortex [11]. McManus posited that Arnheim's understanding was originally influenced by Denman Ross, endorsing a more explicit physicalist methodology [5]. Generally speaking, while viewers are certainly influenced by perceptual forces when appreciating an image, and the perceived center tends to gravitate toward the equilibrium of these forces, this balance point does not necessarily coincide with the geometric center of the frame, nor even lie near it. The experience of a composition is subject to a variety of visual stimuli, of which the equilibrium of forces is just one factor. The effect of the golden ratio in pictorial composition also conforms to the principle of force equilibrium, and is even more consistent with the characteristics of human visual physiology.

3.1. The golden ratio and visual physiology

The emergence of subjective dynamic balance in aesthetic appreciation is rooted in the physiological structure of human vision. Studies in visual physiology have demonstrated the phenomenon of the dominant eye, also known as the leading or preferred eye, which refers to the eye that provides dominant input during binocular vision [12]. When the inputs from both eyes are fused, regional imbalances can affect the overall strength of binocular signals, and the relative dominance of each eye may shift across different parts of the visual field [13].

The fundamental reason for this phenomenon lies in the uneven distribution of cone photoreceptors in the human retina, with the fovea exhibiting the highest density [14, 32]. This arrangement has a significant impact on visual acuity, which peaks at the center of the retina and rapidly diminishes toward the periphery, forming a pronounced sensory gradient. Due to the concentration of cones at the center of the retinal neural structure, sensitivity is biased toward the center. Under the influence of the dominant eye, the center of the combined visual field does not coincide with the geometric or physical center of the perceived image [16].

3.2. The golden ratio and visual psychology

Due to the influence of the dominant eye, binocular vision (including both the visual field and visual acuity) undergoes complex integration and competition, eventually achieving equilibrium through adjustment [17]. Once this balance is reached, a common visual field emerges. Visual balance within an image is a matter of subjective perception and is influenced by a variety of factors; disruptions to the structure of balance can shift the perceived center of equilibrium [18].

The perceptual center of a composition refers to the average location where all viewers direct their gaze when observing a particular painting. This perceptual center does not necessarily coincide with the geometric center of the canvas [19]; rather, it functions as the "center of gravity" in the perception of composition. It also corresponds

to what Dondis described as the "felt axis," which divides the composition into vertical and horizontal quadrants, or to the "balance center" described by Arnheim [7, 20]. In essence, the perceptual center of a composition is subjectively determined—it represents the comprehensive center of gravity of visual elements within the image and serves as the balance center of the composition.

When a visual field is projected onto an image, its center is inherently subjective, as is the visual field center itself and the visual center [21–23]. The center of the visual field does not always align with the objective center, as studies have demonstrated the existence of a subjective center [15]. The subjective visual field center generally coincides with the subjective visual center and the perceptual center of the composition. However, the objective center of the visual field, affected by physiological factors, may be displaced from the symmetrical center of the visual field. During the appreciation of an image, visual attention guides viewers toward the subjective visual center, giving rise to a sense of subjective visual balance.

3.3. Golden ratio composition and aesthetic preference

How do the combined visual, physiological, and psychological phenomena influence visual appreciation? This is closely related to the structure of visual physiology and the use of golden ratio composition. During visual appreciation, elements within an image act as aesthetic stimuli that capture visual attention—for instance, aesthetic images in a visual search task are able to attract attention more rapidly, thereby initiating processes of aesthetic processing and experience [24]. Eye-tracking studies have shown that, under the influence of visual attention, the process of aesthetic appreciation typically begins with visual scanning. In the initial phase of visual search, viewers first perform a general scan of the visual object; when a visual stimulus is encountered, they then focus on it or repeatedly scan it, ultimately fixating on a particular region of interest for detailed visual processing [25]. If the point of visual interest during this processing coincides with the center of the visual field (the balance center of the image), it is likely to evoke aesthetic pleasure.

So, where exactly is this subjective visual center, or balance center? Will placing the main stimulus at this balance center elicit aesthetic fluency?

Experiments by McManus and Weatherby demonstrated that people have a spatial preference for placing objects within a graphic area, with the golden ratio point being the most preferred horizontal position. Tyler, through systematic studies of Renaissance and later portraits, found that artists tend to place one eye horizontally at the center of the portrait and the other eye vertically near the golden ratio [11, 26]. According to Tyler, such compositional arrangements not only produce visual balance and beauty but also tend to evoke aesthetic preference.

3.4. Golden ratio composition and aesthetic processing

Compositional structures based on the golden ratio are highly compatible with human visual physiology, easily evoking aesthetic preference and processing fluency. But why does the golden ratio composition possess visual appeal, and does aesthetic experience in art have an objective, biological foundation?

Di Dio and colleagues investigated the aesthetics of the golden ratio using functional magnetic resonance imaging (fMRI). Their studies revealed a natural preference for golden ratio proportions and showed that objective features of an artwork, such as specific compositional parameters, can evoke distinct neural activation patterns in observers' brains. When participants viewed images structured according to the golden ratio, regions such as the right insula, lateral occipital cortex, and prefrontal areas were activated, indicating an objective neural response to beauty [27].

De Bartolo further explored golden ratio aesthetics through eye-tracking methods, finding that participants generally exhibited a marked preference for golden ratio proportions. Visual fixations were concentrated in regions corresponding to the golden ratio within the image [4]. This phenomenon can be explained by the higher visual impact of compositional elements positioned near golden ratio points or points of interest; these elements more readily attract visual attention and elicit aesthetic preference [9].

4.1. The general process model of aesthetic processing

Golden ratio composition, owing to the structure of human visual physiology, readily induces aesthetic fluency. But what is the mechanism for the aesthetic processing of such compositions? This can be analyzed using aesthetic processing models.

Graf and Landwehr proposed a dual-process model of aesthetics—the Pleasure-Interest Model of Aesthetic Processing (PIA model) [28]. According to this model, aesthetic processing can be divided into automatic processing and controlled processing. Automatic processing is an unconscious, stimulus-driven process, whereas controlled processing is a conscious, purposeful process that allows for more detailed evaluation of the stimulus. If a stimulus draws sufficient attention from the observer, controlled processing may be triggered, overriding the automatic response. When a perceiver's need for cognitive enrichment or capacity for stimulus processing motivates further engagement, complex, perceiver-driven processing will occur. This can lead to nuanced, fluency-based aesthetic judgments such as interest, boredom, or confusion.

According to the PIA model, viewers first engage in automatic processing of a golden ratio composition—a rapid, unconscious response to the aesthetic stimulus. If this configuration is readily accepted, it generates fluency-based aesthetic pleasure, which can then facilitate further detailed (controlled) processing of the golden ratio image. However, research by Graf and Landwehr suggests that the effect of stimulus fluency on attractiveness is fully mediated by feelings of aesthetic pleasure, particularly during automatic processing [29]. This would imply that, in the absence of pleasure or fluency, further controlled processing would not occur.

However, in reality, disfluent compositions do not necessarily produce displeasure; rather, viewers may repeatedly scrutinize the image and continue to process it based on their aesthetic experience, sometimes developing aesthetic interest, which then motivates further controlled processing.

4.2. Aesthetic processing of golden ratio balanced composition

During subjective visual appreciation, the overall organizational structure of visual balance readily attracts the viewer's attention. Artists and art theorists commonly assert that the "induced structure" generated by a balanced configuration is established spontaneously by the visual system. This structure determines how the elements within a composition are visually scanned, interpreted, and evaluated [6]. The aesthetic use of the golden ratio represents a method, whether objective or subjective, by which individuals employ their physiological characteristics during aesthetic appreciation to achieve aesthetic pleasure. It exemplifies dynamic aesthetics and subjective visual balance.

Under the influence of attentional cues, the eyes explore target objects through both saccades (scanning) and fixations. During eye movements, scanning and fixation combine to support aesthetic judgment and processing. Molnar proposed that the initial fixations are guided by a cognitive need, satisfying viewers' curiosity about the content of the image [30]. These so-called "cognitive fixations" globally explore the visual field, primarily directed by image features that attract visual attention. Once a global impression is formed, viewers engage in a detailed

examination of visual features related to possible syntactic and semantic relationships. Scanning represents holistic exploration, while fixation enables further processing; this cycle can last several seconds—or fractions of a second—and is characterized by rapid, reciprocal alternation. Within just a few seconds, viewers repeatedly scan the focal point and compare local details to the overall atmosphere [31]. The processing of golden ratio compositions that possess subjective balance also demonstrates these characteristics of scanning and fixation.

5. Research summary and outlook

The aesthetic processing of golden ratio compositions exhibits the characteristics of dual processing. In aesthetic activities, under the guidance of visual attention, viewers first engage in scanning and fixation of target objects. When a golden ratio stimulus is encountered, automatic processing happens instantaneously. If the balance structure of the image aligns with the viewer's subjective sense of equilibrium—that is, if the subjective and objective balance centers coincide—the viewer experiences a sense of fluent beauty. Conversely, if the composition does not conform to the perception of visual balance, the aesthetic processing is hindered, prompting the viewer to actively seek new points of stimulation for further aesthetic reprocessing. The processing of golden ratio compositions is marked by a balanced structure that facilitates aesthetic fluency and pleasure. During the act of appreciation, the compositional rules and intentions embedded by the artist in the image are recognized by viewers through the mechanism of composition, enabling the enjoyment of beauty.

Disclosure statement

The author declares no conflict of interest.

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