The status of form-giving and geometry in design

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ABSTRACT

Within the context of geometry-driven form giving, this article aims to provide an understanding of how geometric design principles influence designers´ practices in developing new 2-D and 3-D products.
First and foremost, a definition of form-giving will be given with respect to geometry. This is followed up by a study of most used geometric design principles, and how these principles influence the practice of form giving in different fields of design. Furthermore, this article questions if the application of geometric design principles will lead to a more creative design, which is supported by a better proportioned and balanced form. It also criticizes the intent of these geometric design principles whether they should be used as a guideline for designing new products or be adopted to retrospectively analyze existing 2-D and 3-D products forms. Results indicate that mathematical, geometric design principles are most suited for the design of 2-D products and interfaces, whereas non-mathematical geometric design principles, especially the Golden Ratio principle, are mostly applied in the design of 3-D products. The article also suggests that design practitioners should experiment with geometric design templates to determine balanced proportions as part of the design conceptualization work, prior to making design decisions which were merely based on technical functionality, manufacturability and usability.

KEYWORDS: Form -giving, Geometric Design Principles, Golden Ratio.

1. INTRODUCTION

When people look at any complex combination of elements in design such as paintings or even the surface of a web design, we see the whole before focusing to the individual parts. This idea of seeing as a whole before focusing on the individual parts is closely related to Gestalt theory. According to Behrens (1998) Gestalt is a German word, which means “Shape or Form”. Gestalt psychology was founded in 1910 by three German psychologists, Max Wertheimer, Kurt Koffka and Wolfgang Koner. The idea behind the Gestalt theory is triggered by the notion that the human brain tends to organize visual elements in holistic, parallel and analog ways. This leads to situations that composition is perceived as a whole.

Behrens (1998) also mentioned and discussed in his articles that the theory of Gestalt `s plays a key role in influencing art and modern design. His views inspired me to study more about the status of form giving and geometric shapes in the design, whereby in my opinion “Gestalt Theory” can be used, not only as a catalyst to understand the development of interaction and graphic design, but also contribute to the development of form giving primarily in product design.

Many examples showed how certain principles of Gestalt psychology were used in interaction design. These principles are proximity, similarity, figure, ground closure. Gestalt theory also plays an important role in the development of particular 3 dimensional forms. Form giving is a conceptual and perceptual process of product gestalt into a physical form (Akner-koler, 2007, p.2). She also mentioned that form giving is an integrated aesthetic process within the overall realm of industrial design processes.

In this article I will discuss several topics affecting the development of geometry and form-giving and how they played an important role in the generation of 2-D and 3-D designs. Firstly, I will elaborate in chapter 2, the different ways of how people determine two dimensions design (2D), interaction design (web design), three dimensional design, as well as mathematical and non-mathematical theories related to specific contexts

Concerning geometry and form-giving, there are certain principles, which have a direct or indirect influence on products that designers design. Some of the designers, architects, engineers and artists have made these principles normative for their work. In the discussion and conclusion part of the article, the status of geometry and form giving concerning the design of three-dimensional products will be discussed in greater detail.

The aim of this article is to provide an understanding of how geometric form giving rules and principles influence designer's practices in developing new 2-D and 3-D products. This has led me to elaborate more on the following research questions:
Q1: What is form-giving and how is it defined with respect to geometry?
Q2: What are the principles of design and how does this influence the practice of form giving in different fields of design?
Q3: Which of these principles are most suited for the design of 3-D products and does the implementation of these principles lead to a more balanced overall design?
Q4: Are design principles to be used as a guideline for designing new products or are they more suited for retrospectively analyzing existing 2-D and 3-D products forms?

2. FORM GIVING AND GEOMETRY

Whenever we discuss form it converges to principles supported by gestalt theory. This gives us the indication that gestalt theory is a central theme in understanding the concepts and processes of applied aesthetics and form giving. According to Dewey (1980) form giving is a field of study, which addresses the understanding of meaning of elements, its relationships, and how these relationships are organized within a unified whole. This definition is aligned with the gestalt theory principles. Within the context of industrial design, Smets, et al. (2006) stated that form giving is mainly concerned with features influencing the aesthetic outer appearance of artifacts and how these complements technical and user functionality as well as construction. Besides this form giving also has a communicative role, whereby its aim is to not only present factual information but also elements of meaning.

The term form giving is derived from the Swedish and German words "*formgivning*" and "*formgeben*" which means to give form as well as color, texture, sound etc. to concept, needs and desires of contemporary society (Akner-koler, 2007, p.21). Furthermore Akner-koler (2007, p.16) defined the concept of form from an abstract perspective with the realization of concrete objects and organization of ideas. As a noun it refers to physical and spatial dimensions that a typical form occupies and activates. As a verb, it can be defined as a procedural activity of craftsmanship, supported by a cognitive process, that drive form giving process using aesthetic methods. She also classified form into two categories; geometrical and organic form. Akner-koler stated that, Sculptor Rowena Reed and Painter/psychologist Alexander Kostellow,

merged geometric abstractions and organic principles into their artwork. Reed and kostellow deconstructed visual abstraction from geometry into forms, movements and relationship with organic principles of growth, movement, tension, gesture, asymmetrical composition etc. (Greet, 2002). Meanwhile In 1915, geometric form was introduced by Oscar Schlemmer to develop anthropocentric constructivism (Wick, 2000). Oscar Schlemmer applied geometric abstractions to the body and choreographed dance movements to study the human body. He emphasized that it is important to learn abstractions through pure, abstract, geometric composition.

Geometrical principles can be used as a tool for analyzing and organizing form, but should be applied in a proper way, because otherwise it would restrict creative thinking and form giving. (Kamehkhosh 2013). Roztler (1977, 11) claims that people use geometry to create alternative visions that reflect the future. This is complemented by the work of Art historian Herbert Read (1992, 14(1964), who said that the modernist artist´s search for a pure abstract form led to the invention of three dimensional work, explaining that geometric form is a way to explore the future. Furthermore, art historian Alfred Bar (1902 - 1981) categorized modern art into two main movements: geometric abstract art and non-geometrical abstract art. Reversibly, the study of geometric forms and structures, new abstractions and meanings may have influenced the modern art movement.

Nowadays to meet the needs of the increasingly demanding user, form development should be approached from multi-dimensional perspectives, such as color, texture, sound, and technology. To be contextualized and integrated with material and technology, form development has become more functional and systematic. The ideological concept that forms giving are about “less is more” is being adopted and practiced in the design of products up till 1970s. By the 1980s from giving was replaced by a more internationally accepted term, which is Industrial Design.

As time progresses, “technology push” and “need pull” phenomena are not the only drivers, which determine the quality of life in first world societies. Concerning these developments, the study of forms and form giving has entered a new era, where meaning making, identity building and branding are future areas for the designer to be engaged with, with respect to research and development. Back to the status of form-giving and geometry in design, mathematical approaches also include elements of creativity. Nevertheless, the mathematical rules and theories, such as Occam’s razor, Hick Law, Fitts Law, Fibonacci sequence and Golden Ratio are used by the designer as tools to benchmark and create forms.

3. PRINCIPLES OF DESIGN

Designers have identified important design and ordering principles that may arouse positive and emotional human reactions. According to Huang (2011) there are 12 principles that are commonly used by designers, engineers and artists in their design practices. I selected 6 principles out of these 12 and added the gestalt principle to it because they are more specifically related to 2-D and 3-D design. These principles are the Ockham’ Razor, Hick law, Fitt ‘s law, Fibonacci Sequences, Golden Ratio, Rules of thirds, and Gestalt. In this chapter the selected principles will be discussed and reflected upon using real-life examples, where possible.

3.1 Ockham’s razor

According to Sugihara Hiroshi (1997) Occam`s Razor, is a 14th century mathematician, who has strengthened the law of parsimony, or the rule of simplicity. The principles stated that “Entities should not be multiplied unnecessarily”. Occam`s Razor´s rule of thumb has guided some of the world`s best and brightest mind such as Isaac Newton. Huang´s (2011) explanation about

Occam Razor principle, re-emphasized that the solution of complexities should not be multiplied beyond necessity though its entities. There are two principles within of Occam`s theory, which are important. These are the Principle of Plurality and The Principle of Parsimony. In summary, Occam Razor´s is avoiding complexity in design, information transfer and development of instruction guides.

3.2 Hick`s Law

Hick`s law is developed by British psychologist William Edmund Hick. It is based on the principle that "The time it takes to make a decision increases as the number of alternatives increases" For example; the greater the number of the alternative buttons will take longer to make the decision to select the right choices (Hick, 1952). According to Huang (2011) Hick`s Law suggests that the availability of more choices means that it takes much longer time and more effort to make decisions. Within the context of design, this law promotes the use of methods for designers to simplify decision making in situations, where he or she is presented with multiple options. This law has fundamentally proven to be effective in the design of software menus, control display, way finding layout.

3.3 Fitt's Law

Fitt`s Law is a model of human psychomotor behavior, which explains the connection between movement and transmission of information (MacKenzie, 1992) It is centered on mathematical equations that are used to illustrate the time it takes to reach a target (Fitt`s, 1992), and is basically an empirical model that explains speed accuracy of human muscles. According to MacKenzie (1992) Fitt`s popular model has been widely used and adopted in many research area including human factor, kinematics and interaction design. As earlier mentioned by Akner-Koler (2007), that form is conceptually determined by physical, and spatial dimensions, dynamic elements, represented through "time to move to the target", as well as "distance from the starting position to the center within the target width"(Fitt`s, 1992), are fundamentally important to be incorporated in the overall form giving of products and graphical user interfaces.

3.4 Fibonacci sequence

The Fibonacci Sequence, name for Leonardo of Pisa, who also went by the name Fibonacci, was first identified in the early 1200s, but previously understood by older India mathematicians. Fibonacci numbers are closely related to Lucas numbers in that they are complementary to Lucas sequences 'Golden Ratio" That simple arithmetic contributes Fibonacci sequence number 1,1,2,3,5,8,13,21,34,55……. . The Fibonacci sequence of numbers is based on this same principle, and describes the characteristics of growth processes which can be found in nature, for instance in the leaf and flower position of plants. Fibonacci sequence is associated with spiral structures, which are prevalent natural elements, a tree growing in a helix-formed pattern. According to Reich (2009) the mathematician Wisner in 1875 proved that a spiral tree construction is an efficient way of maximizing the capture of sunlight. In nature, we can easily find that almost every living object embodies certain physical spiral characteristics and arrangements. This arises, for example, in left and right handed spirals with a ratio of 8 to 13 or 21 to 34 (all numbers in the Fibonacci sequence.) When dividing these numbers the result is always 1.618, which is known as "Phi" or the Golden Ratio.

3.5 Golden Ratio

The Golden ratio is actually similar in terms of mathematical relationships to the Fibonacci sequence. Leonardo of Pisa who introduce it to the Europe eight hundred years ago along with the decimal number. Elam (2001) highlights that the Parthenon`s in Athens is an example of proportioning as well as element of the façade by golden rectangle. The famous

modernist Swiss architect Le Corbusier centered his design philosophy on the golden ratio and Fibonacci series. Elam (2001) indicated that Le Corbusier explicitly used of the golden ratio in the design of his modular systems to explore architectural proportions Examples are shown in his work "The Modular-A Harmonious Measure to the Human Scale Universally Applicable to Architecture and Mechanics". According to Elam (2001), Le Corbusier presented in his work, geometrical principles that valuable to the designer, artists and architect.

3.6 Rule of third

The rule of third is one of the main rules in art and in photography composition theory. The principle is derived from the Golden Ratio theory and is based upon the proposition that the human eye naturally gravitates to intersecting points of an image that is divided into 3 x 3 sections. The rule of thirds is built upon an imaginary grid, comprising of two vertical lines and two lines horizontally, which crosses each other, making nine sections. Normally professional photographers capture any image using this Rule of third principle, because it always gives the best composition in a photograph.

3.7 Gestalt

In Gestalt psychology form perception deals with how humans perceive elements of an object and out of that develop a mental picture of the holistic object through the perceptual organization of these elements. In accordance with gestalt (Behrens, 2004), Max Wertheimer published "The theory form" in 1923, where he illustrated objects through abstract patterns of dots and lines, assuming that humans have the ability to constellate. Wertheimer´s theory on Gestalt is supported by Chou (2011), as the latter claims that gestalt theory attempts to describe how people tend to organize visual element into group such as proximity, similarity, continuity, symmetry, and closure apart. Gestalt principles assist in organizing perceptual information into coherent patterns.

4. DISCUSSION

The status of form giving and shape geometry with respect to design principles influences the practice of form giving in the different fields of design. These design principles are shown in table 1. and reflected upon whether they have a relevant connection with mathematical and / or non-mathematical theories. The * sign indicates relevancy.

	Principles of design	**Mathematical theory**	**Non mathematical theory**
1.	Occam`s razor	*	
2.	Hick Law	*	
3.	Fitt`s Law	*	
4.	Fibonacci Sequence	*	
5.	Golden Ratio	*	
6.	Rule of third		*
7.	Gestalt		*

Table 1. Principle of design (mathematical and non-mathematical theory)

Occam's razor, Hick Law, Fitts Law, Fibonacci sequence and Golden Ratio have their foundation from mathematical theories. For example, the theory of simplicity by Occam`s Razor influenced the development of websites, such as Panera and Shoping.com. The website founders, Jason Fried and David Heinemeier Hanson used the open-source programming framework to produce these resourceful websites.

Hick´s law is used by designers as a reference for understanding how users manage multiple input sources and make decisions over a period of time. Based on this reference, it also provides a guideline for designers to simplify and make the website lay out more efficient. Fitt`s law complements Hick´s law by introducing

mathematical elements, which can enhance accuracy and speed when navigating the website. Golden ratio and Fibonacci numbers are common mathematical ratios that were instigated by nature and that can be used to create form compositions in design work. Fibonacci sequence and Golden Ratio principle are foremost used in 2 dimensional design (2D) and 3 dimensional designs (3D). For example, Leonardo da Vinci for example, made extensive use of the golden ratio to create pleasing compositions in his famous painting the last supper. The composition of how people are projected across the canvas in relation to each other, showed an almost perfect arrangement according to the golden rectangle
In architecture Le Corbusier used the Fibonacci sequence to design integrative systems comprising of human proportions and sizes, sitting posture and sitting object. Le Corbusier`s two books, Le Modular I published in 1948 and Le modular ll 1955 argues that harmonious proportions are important for everything, from the sizes of the cabinets and door handles to buildings and urban spaces. Fibonacci sequence as known as phi has contributed significantly in elevating the aesthetics, balance and harmony of some of the world`s greatest art works and architecture.

Golden ratio is also frequently used in the design of everyday consumer products. For example the Hewlett Packard HP12C financial calculator has been designed according to a dimensional ratio of 1.6129, which is derived from the Golden Ratio theory. With respect to transportation design the golden ratio has been frequently used in the design of a wide variety of form features of cars. For example, major car manufacturers, such as Toyota, Nissan, Mazda, etc. used the golden ratio in the design of their logos. In the Toyota example, the golden ratio determined the width of the vertical and horizontal oval shapes of the logo.

Concerning Rules of thirds and Gestalt, I classified two principles under the psychologist / non mathematical category. The rules of thirds are rules of thumb or guidelines, which are applied in to the process of composing images such as designs, paintings, photographs and films The Rules of Thirds emphasizes on balance and the creation of a unified whole of the image.
Another non-mathematical form theory is Gestalt, which is psychological in nature and has been researched by German psychologists since 1924.

Gestalt principles have also influenced the practice of form in 2 D and 3-D design. A 2-D example is illustrated by Moore and Fitz (1993), where Gestalt has been applied in showing organized structures and pattern that are being used in document and graphic designs. According to (Chang, et.al 2002) gestalt has also been used to improve form elements of educational screen designs, illustrating benefits of new multimedia technology for designers.

In product design, Gestalt principles organize perceptual information into coherent patterns based on graphic properties (Murray et. al 1998). The advantage of using gestalt principles is argued by Chou (2011), as they provide important perspectives on visual perception, highlighting how minimalist principles can be used to assess the quality of product designs.

	Principles of design	Web design\ graphic design	Painting\ photography	architecture	Product design	Furniture design	Transport design
1.	Occam`s razor	*					
2.	Hick Law	*					
3.	Fitt`s Law	*					
5.	Fibonacci Sequence	*			*		
6.	Golden Ratio	*	*	*	*	*	*
7.	Rule of third	*	*				
8.	Gestalt	*			*	*	*

Table 2: Design category influence by principles of design.

Table 2 above shows a categorization of different design field according to the earlier discussed principles of design. The table clearly indicates that the Golden Ratio principle is most versatile for the designer to use in the development of 2-D and 3-D forms. However, the Golden Ratios has a strong presence in web design demonstrating how ideas and concepts for design applications are to be communicated to the user. As an example the editor of web design HONGKIAT.COM Chris Pentago presented in his article that the golden rectangle method is often being used in the layout design of his websites. From an art perspective, Leonardo Da Vinci explored the human body according to dimensional ratios of body parts, which he illustrated in his famous painting, exemplified by the Mona Lisa, the old man and the Vitruvian man.

In the field of architecture, it has been suggested that the Golden Rectangles and Sections were applied in the design of the Notre Dame and Taj Mahal. Le Corbusier explicitly used the Golden Ratio in his modular systems to determine architectural proportions.

Concerning industrial design, the Golden Ratio principle has proven to be useful in improving the aesthetic impression of a product by stressing on harmony and balance of elements and features of the overall form (Avramovic, et.al 2013). An example of how this principle has been applied in Industrial Design is shown in the case study of the Dyson vacuum cleaner (Avramovic, et.al.2013). In this case study, the Golden Spiral Methods was directly applied to determine the overall form and relationships among form elements of the vacuum cleaner show at table 4 below. Furthermore the forms of the vacuum cleaner itself, as well as the underlying principle to generate this form and form elements were tested by a panel of potential users to confirm the correlation between the designed object and design principle.

Another Industrial Design example, where the Golden Ration has been adopted, is the Hewlett Packard HP12C Financial calculator, which was introduced to the market in 1982 as a part of the HP Voyager Series. The official dimensions on the HP site were closer to 1.618 of Golden ratios. In this case, the dominant sub-categories of the Golden Ratio, which were used to design the HP 12C Financial Calculator, were the Golden Section Rectangle and Square Construction Method.

The final Industrial Design example, shows how Aldo Rossi´s ll Conico kettle, which is composed by basic geometrical shapes and to form one unified functioning entity, adheres to a geometrical structure that uses a 3 x 3 grid (see figure 1). (Elam, 2001)In furniture design, the use of the Golden Ratio has been exemplified in Mies van der rohe´s cantilever armchair, or MR chair, which was designed in 1926 (see figure 5).

According to Elam (2001) several geometrical methods belonging to the Golden Ratio group were used to analyze the design. As a result the Square Construction Method has been used in the top view to define the chairs proportions, whereas the Golden Section Rectangle was predominantly applied in defining the proportions of the side and frontal views of the chair.

According to Elam (2001) the Volkswagen Beetle is a good example where Golden Ratio principles have been applied in transportation design. In this particular example, the Golden Ellipse geometrical method matches exactly the middle part of the vehicle, as shown in table 6 below. Furthermore, the side view outline of the beetle is tangential with two circles and the Golden ellipse. This case example does not only illustrate the relevancy of using Golden Ratio principles in transportation design but also demonstrates that certain methods belonging to the Golden Ratio, such as the Golden Ellipse are more suited to proportion curved shaped.

Principles of design	**Product design**	**Furniture design**	**Transport design**
Golden Ratio	(Il Conico 1980-83) kettle Aldo Rossi 2.Vacuum Cleaner Dyson (James Dyson 3. Hewlett Packard HP12C financial calculator. (William Hewlett and David Packard)	MR Chair 1929 Cantilever armchair Mies van der Rohe	Volkswagen Beetle 1997. Schreyer, Jay Mays, Freeman Thomas.

Table 3: Product, furniture and transport design analyzing by golden section geometrical method.

As summarized in table3, the Golden Ratio principle is most suited for product, transportation and furniture design. To be more specific one can also identify geometric methods, belonging to the Golden Ratio principle, which were used to define and proportion the product as a whole as well as certain form features. The collection of geometric methods, which are part of the Golden ratio, are: Square Construction Method, Golden Section Spiral Method, Golden Section Rectangle, Triangle Construction Method, Golden Section Proportions, Golden Section Triangle, and Ellipse frequently used to analyze 2D and 3D design.

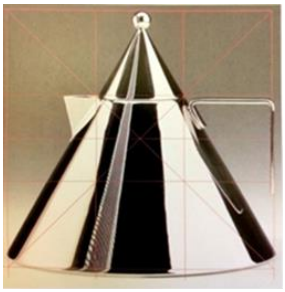


Figure 1: Il Conico kettle analyzed using the Rule of Thirds as a geometrical method.

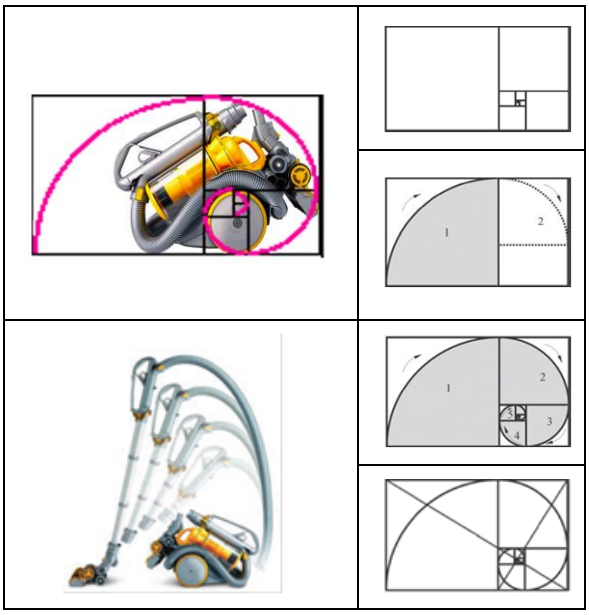


Table 4: Dyson applied by Golden spiral method.

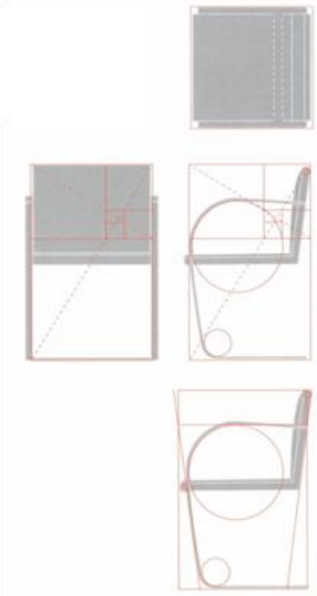
	
Cantilever armchair MR Chair 1929.	Square construction method

Table 5. Cantilever armchair analyze by golden square method.

Figure 2:(Above) HP 12c Financial Calculator (Below)Rectangle and Square Construction Method.

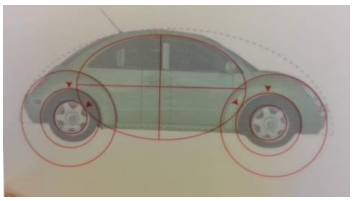
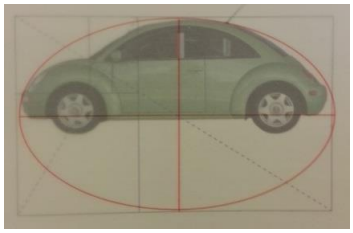
Geometry construction method.	
Golden Ellipse. Enclose to the window. Tangent to the both front and rear wheel.	
Geometry construction method.	
Golden rectangle construction. Fits neatly with the body especially into the half top body of the car.	

Table 6 (Above) Geometry construction method (Below) Figure 2 Volkswagen Beetle by Jay Mays, Freeman Thomas, and Peter Schreyer 1997)

5. CONCLUSION

In this article, I have evaluated the influence of design principles on how form giving and geometry is being applied in the design of products. With respect to the first research question, geometrical principles can be used as a tool for analyzing and organizing form, but should be applied carefully. An overemphasis and over-reliance on geometric principles may restrict creativity in form giving.

Literature studies have revealed 6 design principles, which are relevant for form development in a selection of design fields. These design principles can be classified according to their connectivity with mathematical and non-mathematical theories. Concerning product design, Fibonacci sequence, Golden Ratio and Gestalt theories are most relevant for analyzing and developing a balanced form. Having a background from design practice, I strongly advocate the use of the Golden Ratio, as it is natural, aesthetically pleasing and most versatile. However, design principles, which are founded in mathematical theories, which are predominantly used in web- and interface designs, should not be underestimated.

The article discussed examples where design principles have or could have been applied successfully in developing creative breakthrough designs. However, no documentation has been found about cases, where the application of design principles did not contribute or even had a detrimental effect on the design output

This gives rise to question whether design principles are to be used as a guideline for designing new products or that they are more suited for retrospectively analyzing existing 2-D and 3-D products forms. I suspect that design principles, especially the Golden Ratio, have been applied in retrospect, which is not a bad thing. However, I see great potential to proactively use design principles for form studies in the conceptualization and refinement stages of the design process

More concretely, I can conclude that design practitioners should experiment with design principle templates to determine balanced proportions as part of the design conceptualization work, prior to making design decisions which are merely based on technical functionality, manufacturability and usability.

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