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APPLYING GEOMETRIC RELATIONSHIP IN PRODUCT DESIGN

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ABSTRACT
Geometry and the golden ratio in art, architecture and design are frequently used as a way to perceive aesthetically pleasing structures rather than as a principle to further develop visual coherence and as a basis for rational decisions in the design process. The aim of this paper is to demonstrate how geometric relationships can be applied to the product design process. It will also investigate how geometric relationships can provide effective design rules which can be practical and directly applicable in design. Geometry workshops were carried out in the Creativity Zone at the University of Brighton and in the Design Studio at the University of Sussex between 2011 and 2012. During the workshops three hypotheses have been tested on product design students to investigate how design practitioners perceive geometry and how the golden ratio in designs may be utilised to recognise harmonious geometry.

Keywords: Geometry, the golden ratio, design principles, harmonic proportion, theory and practice

1 INTRODUCTION

Geometry is one of oldest sciences and a branch of mathematics which has been used since ancient Greece and Egypt. In particular the implication of the golden section, 'phi' in art architecture and design were known as a guideline of aesthetic beauty. Artists, architects and designers, such as, Leonardo da Vinci, Le Corbusier, A.M. Cassandre, designers such as, Dieta Rams and Jonathan Ive have carefully and rationally embedded geometry in their works. All of which have been regarded as masterpieces or well known and respected good examples of designs in design history. However, learning and applying geometry in product design at BSc degree level is still a new area which needs to be explored to develop this tool as a basic principle for design practitioners. This paper shows how geometry could be a useful skill to improve design practitioner's visual coherence and advanced awareness of aesthetic forms and styling.

2 GEOMETRY IN ART AND DESIGN

Researchers in aesthetics and psychologists have investigated geometric forms as stimulus objects in order to understand the aesthetic feelings about the objects. The first researcher who studied the aesthetic preference of the golden section rectangle was the famous German psychologist Gustav Fechner, in 1876. His subjects chose from the most–preferred to least-preferred among ten rectangles of varying proportions from 1:1, 5:6, 4:5, 3:4, 7:10, 2:3, Φ, 13:23, 1:2, to 2:5. He gathered a total of 347 responses and his experiment shows that 35 % of people preferred the golden section rectangle and that no subject chose the golden section rectangle as their least favoured choice. The least preferred rectangle chosen by the subjects was the 2:5 with 35.7%. Other researchers repeated the experiment, such as Witmar (1894), Lao (1908) and Thorndike (1917) and all outcomes remained similar to the original. Not all studies done would agree that people are attracted to the golden section rectangle. For example, Berlyne's work (1970) suggests that cultural factors could be influential toward the chosen preference of different sized rectangles or squares. This was the result of his experiment which showed evidence that Japanese high school girls preferred squares rather than the golden section rectangle. Fischler (1981) claimed there was no sufficient documentation to support the theory that an artist used the golden ratio as the theoretical basis of his work. David and Jahnke's research (1991) would also suggest there is not enough solid data gathered to be a decisive factor in terms of aesthetic preference for the individual choice. They concluded that their experiments "provide no basis for the golden section as an aesthetic ideal"[2]. Whilst both these studies produced results that

seem to place less emphasis on the golden ratio as a design concept the results are by no means conclusive in any way. Fischler, and David and Jahnke in their own words both mention a lack of sufficient data when attempting to write a conclusion to their research. This does not constitute conclusive proof of anything. There are as many, if not more, examples of the reverse actually being the case. Others, such as Jay Hambidge -who analyzed Greek vases based on his theory of 'Dynamic symmetry'- discovered that the root rectangles (√2, √3, √4 and √5) and the golden section rectangle were used for Greek vase design. He suggested that ancient Greek artists and designers were consciously experimenting with geometry and frequently used the golden ratio and the root rectangles all of which are deeply embedded in ancient Greek design. Whilst not all of le Corbusier's works exhibited the use of geometry and the golden ratio deliberately, many of his works such as Chaise Lounge (1929), Façade of the Arsenal of the Pirates (1931) and Villa Savoye (1931) were his examples of applying the golden ratio. More recently Kimberly Elam in her book 'Geometry of Design' describes how geometry can be a useful tool for analyzing designs. A number of graphic designs and product designs were carefully analysed by applying geometry and the golden ratio.

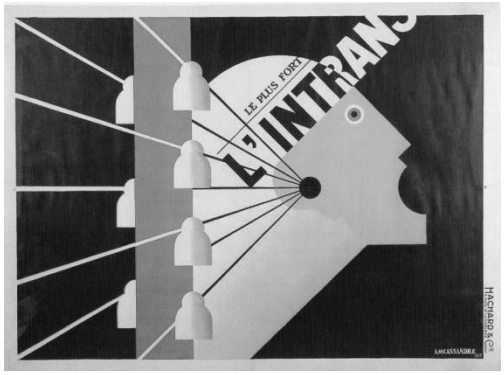

Figure 1. L'intransigeant poster [3]

For example, A.M Cassandre' L'intransigeant Poster in 1925 (see figure 1), illustrates how artistic creativity had been expressed under consciously planned geometric composition, proportion and harmonious subdivisions. All this may suggest that this geometric process in product design could help students to improve their visual coherence and harmonise design forms. The visual format of the original poster shows a square inside of a root two rectangle with the face and neck organized inside of the square.

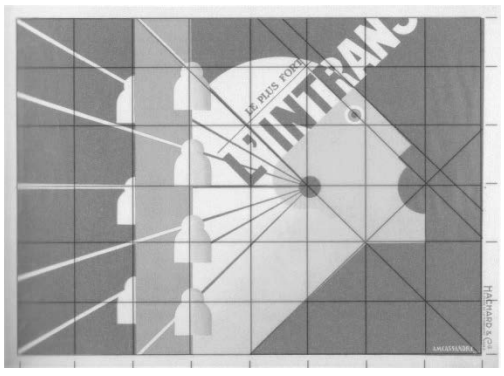

Figure 2. Geometric analysis of L'intransigeant poster [3]

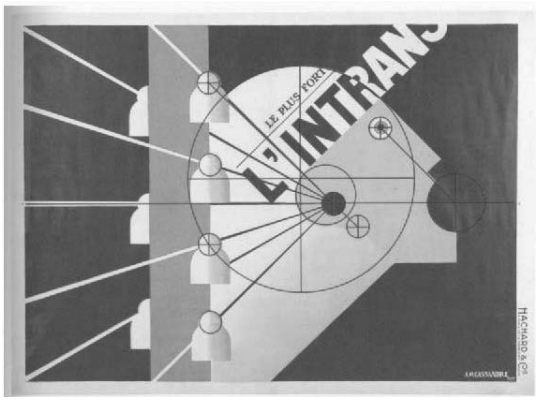

Figure 3. Geometric analysis of L'intransigeant poster

To illustrate how every element of Cassandre's designs used geometric harmony figure 2 shows subdivisions of the poster within 48 small squares and diagonals of the square in side of the root 2 rectangle. The 'L' displays at the centre of the poster while the angle of the text, 'L'INTERANS' and the neck lines are carefully designed to be paralleled within dynamic motion. In particular figure 3 shows how Cassandre utilized the more aesthetically pleasing notion of the circle to attract viewers attention. All of the circles in figure 3 are directly proportionate to each other for example the head circle is 4 times the ear circle etc. [3].

3 APPLYING GEOMETRIC ANALYSIS IN PRODUCT DESIGN

Geometry workshops were carried out in the Creativity Zone at the University of Brighton and in the Design Studio at the University of Sussex between 2011 and 2012 two times (2 hours each). The workshop was designed to introduce a group of 35 second and third year BSc Product Design students (1/3rd female and 2/3rd male) to analyse their own designs using geometry and the golden ratio. The geometry workshop explored ways to expand creativity through a series of exercises, including learning how to use and apply the golden ratio and geometric analysis. This workshop aimed to show students how to be able to apply geometry to their own designs naturally in order to develop visual coherence through geometry practices and to help design practitioners to communicate effectively - where necessary - to support design decisions with rational explanation. Ultimately each design practitioner will be able to find their own way towards using geometry as a design tool for stimulating their artistic skills, creativity and sensitivity. The workshop process had three steps: 1) questionnaire, 2) learning geometry and applying geometry to analyse designs and 3) reviewing assignments and discussion regarding the pros and cons of implementing geometry into their own design and how would design practitioners perceive geometry and geometric analysis as effective design rules?

3.1 Questionnaire

Question 1 – asked students whether they were familiar with the 'golden section', the 'golden ratio', the 'golden mean', the 'golden number' or the 'divine proportion' (these all refer to the same concept).
Question 2 – asked students what the specific numerical ratio or proportion of the 'golden section' is.
Question 3 – was a test asking students to choose a favourite from 'A' to 'F'. 'C' was the only option which conforms to the Golden Ratio. None of the students were aware of which of rectangle was the golden section rectangle (see figure 4).

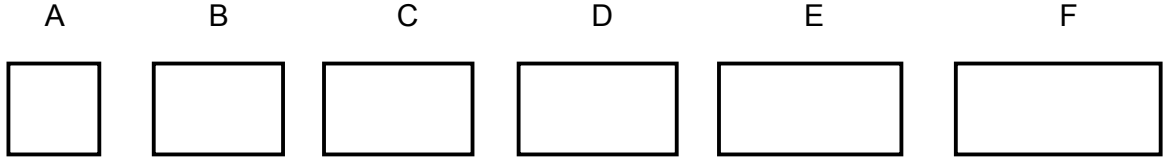

Figure 4. Question 3

Question 4 – students were asked to choose their favourite rectangle between 'A' or 'B'. Rectangle 'A' is the same ratio as the iPod classic (1.67) and 'B' is a rectangle constructed from rectangle 'A' which has been modified to conform to golden ratio proportions (1.618) (see figure 5).

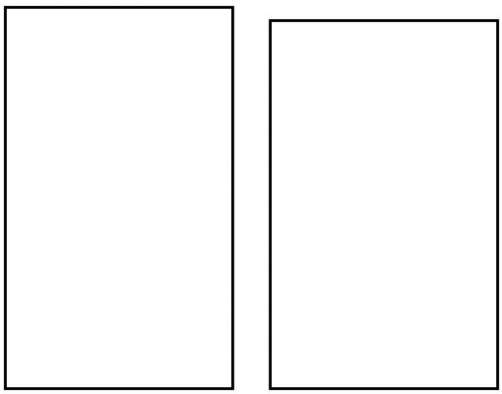

Figure 5. Question 4

3.2 Findings

35 students completed the questionnaire regarding geometry and the golden ratio. Although the majority (31) of students were familiar with the concept of the golden ratio, only four students knew the value of the golden ratio, '1.618' and four students had not heard about it whatsoever. It appears - from data collected in question 3 that the golden section rectangle is most attractive to viewers and the second favourite choice is root two rectangle. The result of question 4 shows that the number of students attracted to the Golden Section rectangle ('B') was 31 of 35, 88.5% of the class. A significantly higher number of students chose the Golden Section rectangle and a mere 11.5% chose the rectangle that does not conform to Golden Ratio principles. This is an important result as one would have expected a much more equal division of choice considering there was no pronounced difference between the sizes of both rectangle options.

3.3 Learning geometry and applying geometric analysis to your design

The students learned how to construct frequently used measures in geometry, such as √2, √3, √4 and √5 rectangles and the golden section rectangle as well as the golden spiral. After learning the basic geometry, students attempted to apply what they had learned in order to analyse design examples. Three exercises were given to students in order to practice geometric analysis. During the workshops three hypotheses were also tested regarding applying geometry analysis to design.

Hypothesis 1; '*Is an intuitive understanding of what constitutes good design linked to a fundamental relationship of geometry?*', Hypothesis 2; '*Does a formal knowledge of geometric rules and visual coherence improve design skills?*', Hypothesis 3; '*Does bad design result when the geometric rules are ignored*?' Hypotheses 1 was used to examine how their perception is linked to geometry and in particular the golden ratio. Also, if design practitioners show a higher level of visual coherence in their designs, do they use geometry and the golden ratio more effectively? And then, how should design practitioners effectively learn and use geometry and the golden ratio in order to analyse designs and also to develop their visual coherence? Hypothesis 2 investigated how design practitioners perceive this geometric exercise in terms of finding their own personal style and to find out if knowledge of geometric proportion has been helpful to them as designers. For Hypothesis 3, students were asked to try not to use geometry in design in order to experiment with their conception and perception and see how they have progressed. This final hypothesis is to analyse whether geometry is useful to them and how intuitively they apply geometric principles without intending to do so. Thus the students completed four experimental assignments which were designed to test the hypotheses.

Assignment 1 – to apply geometric analysis to your design and find out what your intuitive geometric ratio is.

Assignment 2 – to refine your original design through applying the golden ratio.

Assignment 3 – to avoid geometric knowledge gained while redesigning your original design.

Assignment 4 – to display all three designs from assignment 1-3 and chose a favourite design and explain the reason for that choice.

4 RESULT

24 completed the assignments. 16 students chose their refined original design to conform to the golden ratio as their favourite design and one student chose his favourite design which conforms to root 5 ratio although his original design ratio, 1:1.987 was close to root 4 (see table 1). Only 7 students chose their original designs as their favourite and their design ratios were close to root rectangle ratios and phi group ratios (see the yellow marked ratios in table 2). Although in assignment 2 they did not necessarily express a marked preference for their 'golden ratio' modified designs, 5 of the 7 students chose the golden section rectangle as their favourite in question 3 and 4 of the questionnaire.

Table 1. Favourite design choice

Designs	Favourite design choice
Original design	7 (29.1%)
Refined original design to conform to the golden ratio	16 (66.6%)
Redesign original design while avoiding geometric principles	0 (0%)
Refined design to conform to root 5	1 (4.16%)

The original design ratios of the students' designs show that their intuitive design ratios almost entirely conform to the golden ratio and other common geometric numerical quantities (see table 2). Thus in total 70 % of the students preferred their refined design which conformed to the golden ratio and root 5 ratio. None of the students chose the design from assignment 3 which had no geometrical knowledge applied as their favourite design overall. The results of the hypotheses in fact correlate with the findings from question 3 and 4 of the questionnaire and patently manifest a high number of students inclined to the golden section rectangle. In addition, after having learned about the golden ratio etc, when they were then asked to redesign their original design without using what they had learned about geometry they struggled with the task. It is interesting that once they had designed using geometric principles they found it difficult to work without it. It appears that their intuitive perception of geometry has increasingly emerged and has become a design consideration.

Table 2. Original design ratios

Ratios	1:1	1:1.2	1:1.3	1:1.4	1:1.5	1:1.6	1:1.7	1:1.8	1:1.9	1:2	1:2.1	1:2.2
Frequently used geometric ratios	1:1	1:1.272 (=√Φ)		1:1.414 (=√2)		1:1.618 (=Φ)	1:1.732 (=√3)			1:2 (=√4)		2:2.236 (=√5)
Original design ratios of the students	1:1.03 1:1.008 1:1.96	1:1.2 1:1.23 1:1.231		1:1.404 1:1.414 1:1.44 1:1.454	1:1.58	1:1.612 1:1.625 1:1.631 1:1.661	1:1.72 1:1.74 1:1.79	1:1.805 1:1.83	1:1.918 1:1.987	1:2.09	1:2.18	

Three student comments below are typical and exhibit their feelings regarding applying geometry in product design.

"It is beneficial to have an understanding of geometry in design as it may help the proportion and ratio of your design that previously did not look right before. It is practical and it will take practice to apply it to my own work." - Tala Jarallah, Product Design Year 2, University of Sussex.

"It is very interesting to see that behind a beautiful design there is geometry, ratios, shapes. Sometimes it is hard to believe that someone actually planned this geometry into mysterious design…I think it can be very beneficial when you are carrying out a design and something does not feel right you can actually try to apply geometry to your design and "fix" what was wrong with it" - Demosthenis Katsouris, Product Design Year 2, University of Sussex.

"Aesthetically it can be good but I am interested to see if geometry and the golden ratio still make the function better" - Catlyn Adams, Product Design Year 3, University of Brighton.

Since being introduced to the idea of using geometry as a design consideration according to student feedback they would all consider applying geometry to their design as a way to refine their work. Learning geometry and successfully applying it to the design process takes time and requires practice. At the end of the geometry workshop the students have more idea how to compare their design styles and forms through geometric analysis. Thus geometry provides a method of analyzing designs and develops an ability to express design concepts rationally when needed. A possibly more effective approach to help design practitioners would be to set specific tasks which involve engaging with and observing geometry in nature and their surroundings.

5 CONCLUSION

The geometry workshops have demonstrated how to apply geometry and the golden ratio into product design as a design tool for analysing or refining designs. The results of the questionnaire and the hypotheses appear to show that the golden ratio is chosen to be one of the favourite design ratios by design practitioners. Also the original design ratios of the design practitioners are close to common geometric ratios which explain how every designer has their own intuitive geometric organization i.e. whether they are actually aware of it or not, they produce designs that conform to geometric principles. However, "in design and architecture it is far less intuitive and far more often a result of knowledge that is thoughtfully applied."[3] The point of learning about geometry and how it relates to design is not to use it as a substitute for the creative process, but rather as a means of obtaining a deeper understanding of it. Without the initial spark of imagination and creativity geometry on its own will not make a good design. One of the aims of this workshop was to explore and analyze students' intuitive sense of geometry. Then to discover ways to apply geometry; to designs in order to produce an end result of a coherently designed product. It is clear that only a few workshop sessions may help design practitioners to obtain tangible benefits from learning how to apply geometric analysis to their designs. In the short term, it would be a useful approach to review their designs to improve them in terms of proportion and composition. For the longer term using geometry would lead to gaining true benefits when it comes to developing creativity and imagination.

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