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Experimental approach to the study of beauty: The role of golden proportion

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Two experiments evaluated the impact of different deviations from golden proportion on subjective perception of beauty. Black and white adaptations of Mondrian paintings modified to fit golden, 1/6 and 1/2 proportions were used as stimuli. Within each trial, participants were exposed to two versions of the same painting on a computer screen. Participants were given 1500 ms to select the one they considered more beautiful. In experimental trials one of the paintings presented the golden proportion while the other presented either the 1/2 or the1/6 proportion. The two paintings were identical in control trials. University students without formal training in art showed preference for golden ratio stimuli over 1/6 stimuli, but not over 1/2 stimuli, both, when they were tested in within-subject (Experiment 1) and between-subject (Experiment 2) designs.

As stated by Pacioli (1509/1991), the golden section is defined as a harmonic division of a line in extreme and mean ratio (see the top panel of Figure 1). A segment is divided according to golden ratio if the following equation is correct: (a+b)/a=a/b. In other words, the total length of a segment (a+b) is to the greater section (a) as the greater section (a) is to the smaller one (b). If a segment has been divided according to the golden section, the value of the relationship between the greater and the minor sections is approximately 1.6180, value that is extracted from the following ratio: $(1+5^{1/2})/2$. This has been called golden number, and it is symbolized with letter ϕ (*Phi*). Similarly, a rectangle in which the ratio between its longer and shorter sides equals the golden number is named as golden rectangle (see the low panel of Figure 1). Finally, although there are

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different types of spirals, the best known ones are the Archimedes spiral (described as the one in which the distance of the coils with respect to the origin grows as a fixed proportion) and the logarithmic or golden spiral (in which the distance of the coils with respect to the origin increases geometrically, based on *Phi*) (Corbalán, 2010).

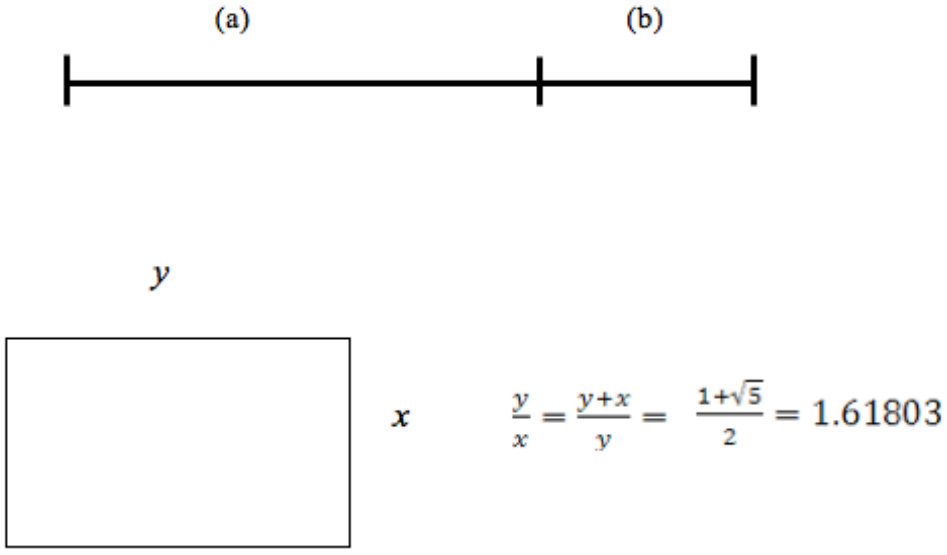

Figure 1. The top panel shows two sides of a segment that keeps the golden ratio. The lower panel shows an example of a golden rectangle and the equation that demonstrates the relationship between the longest side Y, and the lower side X.

Golden number, Phi, or the divine proportion, has been considered as one of the essences of beauty perception, and it is on the foundations of classical arts. Taking just a few examples, the design of the Parthenon at the Acropolis of Athens is based in the golden proportion. Centuries later, Leonardo da Vinci represents the golden proportion of the human body in his Man of Vitruvio (Pacioli, 1509/1991); Jan Vermeer, the well-known 17th century painter, used this proportion in his work, and, within the 20th

century, Piet Mondrian, the famous Dutch painter, structured his abstract painting following the rules of the golden section (Deischer, 2004).

Golden section also appears as a growing pattern in different biological systems (Doczi, 1996; Hemenway, 2008). For instance, golden ratio is found in the equilibrium between the height of a human being and the height to the navel, in the ratio between the length of the arm and the section formed by the forearm and the hand, in the human face, in the cardiac rhythm in which the heart's ventricles recover their initial position, or in the Nautilus's shell, that develops as a golden spiral (Doczy, 1996). Within the plant kingdom, Brousseau (1968) analyzed 4.290 pine cones of ten different species of pine trees finding that golden proportion was kept in all but 74 of them (1.7%). Similarly, Jean (1992) found that golden proportion was observed in more than 92% of all the possible cases of plants with a spiral disposition of their elements.

However, it is not until the 19th century when the first empirical study about the relevance of golden section on aesthetic perceptions is reported (Fechner, 1876/1997). Fechner presented to participants lacking aesthetic education a set of ten white rectangles on a black table, ranging in size proportion from 1:1 to 2.5:1. They were requested to select the one they liked the most, and then, many of them were requested to choose the one they found least pleasing. Rectangles' area was identical, to control for the possibility that the people's preferences were affected by the sheer size of the figures. Of the ten rectangles Fechner used, the golden rectangle ranked seventh, in order of long-to-short ratio. That is, there were six figures with lower ratios, and three figures with larger ratios. Fechner's participants gave a total of 347 responses. Of those, 35% expressed a preference for the golden section. An additional 20.6% expressed a preference for the 1.5:1 rectangle (the next least elongated), and 20% were for the 1.77:1 rectangle (the next most elongated). Preferences dropped off quickly on both tails of the distribution. By contrast, none of the participants selected the golden rectangle as the least pleasant and only 1.4% selected rectangles immediately adjacent to it. The least favored rectangles were the 2.5:1 with 40.9% of selections, and the square with 31.9% of selections. Witmer (1894) replicated Fechner's studies, extending them to triangles and other figures as well. Unlike Fechner, Witmer presented his figures serially, one at a time. He found that the most preferred rectangle was a 1:1.65 side-to-side ratio, a figure quite close to the golden section.

At the same time, Pierce (1894) conducted a study in which he used three parallel vertical lines 10 cm. long by 5 cm. wide. Two of the lines were presented 60 cm. apart. Participants could move the third one, placing

it between the other two. Six participants were asked to choose the "most agreeable" position for the middle line. Pierce (1984) reported that everyone chose a position roughly corresponding to the golden ratio as the most agreeable one for the third line. When the number of fixed vertical lines was increased, participants tended to place the moveable line at a position equidistant from the two fixed lines that were closer to the golden section. For instance, participants that were exposed to lines at 0 cm., 20 cm., and 60 cm., and were asked to place a fourth between the latter two, tended to place it at 40 cm. Pierce interpreted this result as reflecting a need for balance between variety and simplicity, an aesthetic theory dating back to the Ancient Greeks.

Note that all the previous studies present participants' mean performance of different individuals, rather than individual accomplishments. Angier (1903) took a different approach, asking nine participants to divide a horizontal line "at the most pleasing place" 72 times each. Only two participants chose the golden section with regularity, suggesting that the golden section is a mathematical abstraction rather than a universal aesthetic ideal (but see Green, 1995). This deviation of preferences from the golden proportion is not unusual. Thorndike (1917) presented participants different sets of twelve rectangles of varying proportions, requesting them to select the rectangle they liked the most, their second favorite, and so on, until they reached the least favorite one. Rectangles were all the same height (so that figures' area was not controlled), all of them were shown in the vertical orientation, and all of them were shown at once, in order of proportion, from the narrowest to the widest. Their height-to-width ratios ranged from 1.3:1 to 3.75:1. None of the rectangles garnered overwhelming support, but the golden rectangle and the next two most-elongated rectangles (1.8:1, 2.0:1) were ranked first, second, or third (out of the twelve rectangles) by 35-45% of the participants. Conversely, only 7% of participants ranked them among the three less favorites. The1.8:1 rectangle had the best mean ranking, a slight deviation from golden proportion.

However, the role of golden ratio in aesthetic preference is not always clear in the literature. Lalo (1908) used Fechner's procedure, asking participants which rectangles they liked the most and which ones they liked the least. Although Fechner's finding about the preference for the golden ratio and the two adjacent rectangles was replicated, 27% of participants preferred one of the rectangles at the two extremes of the range. More recently, Boselie (1992) found no greater preference for the golden rectangle than for the 1.5:1 rectangle in his study, concluding that the

golden section has no special perceptual aesthetic attraction (see also Godkewitsch, 1974).

The studies summarized above used simple stimuli, casting doubts about whether they may be useful to explore human aesthetic preferences (Arnheim, 1986; Marty, 2002). Konecni (1997) took a different approach, using vases that were presented in a laboratory, purpose-built, mantelpiece. Participants were requested to give an aesthetic judgment on the vase that seemed the most pleasant, finding that nearly 50% of participants chose the golden ratio proportion vase over other vases that did not keep the golden proportion. In similar lines, Konecni (2001) analyzed 95 paintings of the 20th century finding that the central axis was displaced towards the golden ratio axis in most of them. Finally, when a group of professional painters were requested to paint different images under the instructions of making it believable, precise and realistic, they represented the golden proportion with greater precision than other proportions regardless of the paintings used as samples (Konecni, 2003). Although the results of these studies seem to show evidence of the aesthetic value of golden ratio when artistic stimuli and professionals are used, artistic works include unwanted variables like complexity, color, etc. that may be affecting aesthetic preferences, limiting the generality of the conclusions of his studies.

The experimental series presented here tried to shed light on these issues. The main goal of the work reported here was to experimentally study whether there is an aesthetic preference related to golden section using complex artistic stimuli, but under experimental conditions more tightly controlled than the ones used in previous studies (i.e., Konecni, 2001, 2003), searching for a compromise between experimental control and art production. Thus, our study searched for serving the dual requirement that is all but absent in the literature: Experimental manipulation of the golden ratio stimuli, and the use of stimuli that may be considered artistic and ecological, at least from the Western cultural perspective.

To pursue this goal, the experiments reported here used artistic stimuli developed from original Mondrian's paintings. Whether the use of the golden proportion in Mondrian's paintings was intended or not, or even whether he used it at all, is something that goes beyond the scope of the present research (see Bouleau, 1963; Prado, 1989; c.f. Wiegand, 1943). In our study, Mondrian works were taken as the base for creating the stimuli that, after an intentional manipulation, presented either the golden ratio or a different ratio, depending on the needs of the research goals.

To evaluate the preference for the golden proportion a pair-choice task was used (e.g., Berlyne, 1971; Berlyne & Ogilvie, 1974). Two stimuli

were presented at the same time to the participants on a computer screen, and they had to select, within 1500 ms., the one they considered more beautiful. This temporal parameter was chosen based on the studies showing that latency for aesthetical processing in the dorsolateral prefrontal cortex seems to be between 400 and 1000 ms. (Cela-Conde et al., 2004; Munar et al., 2012), leaving a few ms more for participants to make the aesthetic judgment.

Main hypothesis is quite straightforward: If stimuli keeping a golden proportion are perceived as more beautiful by participants, they will be selected more often than the comparison stimuli. Experiment 1 used a within-subject design to test the preference for golden ratio stimuli with respect to stimuli that kept proportions of either 1/6 or 1/2. In Experiment 2 this comparison was conducted in a between-subject design that allowed for controlling for differences in familiarity with the different stimuli.

EXPERIMENT 1

The goal of Experiment 1 was to explore empirically the aesthetic preference towards golden section in laboratory conditions. The use of simple polygons such as the ones used by Fechner (1876/1997) makes the translation to the pretended relationship between art and perceived beauty quite difficult (Nadal, 2007). In Stimuli in this study were black and white adaptations of 5 original Mondrian's paintings with 3 versions for each painting: one in golden ratio, one in 1/2 ratio and the last one in 1/6 ratio. Stimuli were presented in pairs and participants were requested to select the one they considered the most beautiful.

Transformation of the original paintings into golden ratio stimuli was conducted in three steps (see the example in Figure 2a). Original painting is presented in Panel 1 of Figure 2a. Note that the shape of the painting kept the golden ratio proportion (13.21cm. x 8.2cm.). This shape was not changed across stimuli versions. As pilot experiments had shown that colour acted as a confounding variable when studying proportion-based aesthetic preference, the first step was to eliminate the colour from the painting (Figure 2a, Panel 2). Following the compositional ideas described by Bouleau (1963) and Prado (1989), lines from the original painting that generated a point of unwanted attention that may disturb the recognition of the proportion of the pictures were removed (Figure 2a, Panel 3). Finally, the inside of the picture was fully adapted to the golden ratio as shown in Panel 4 (or the selected proportion) both, in the division of the lines and the shape of the rectangles. As a result of this process, we ended with the

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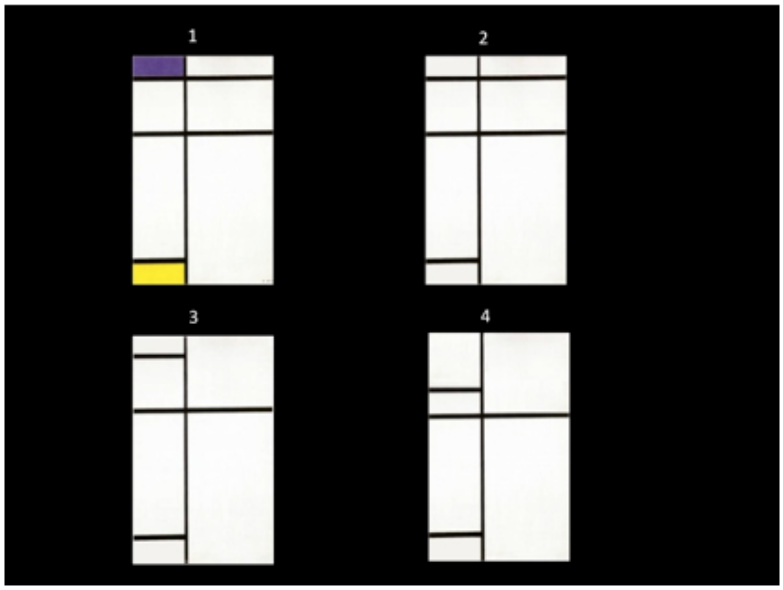

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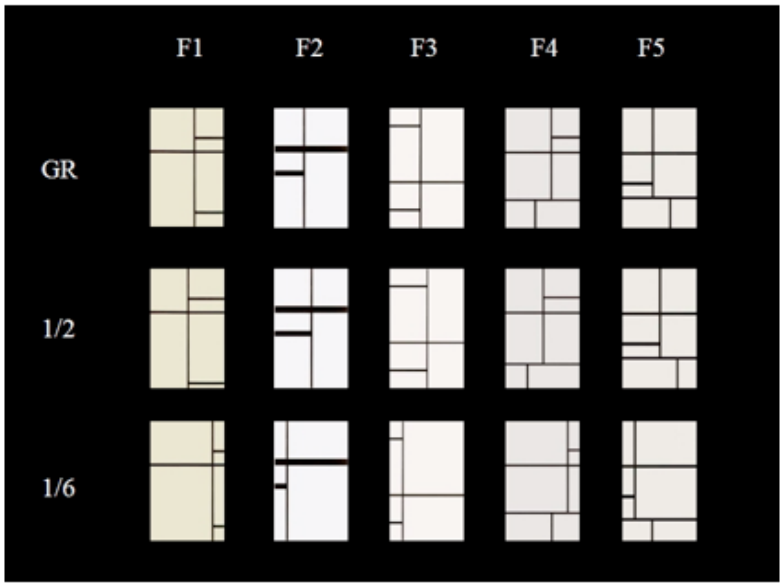

Figure 2. Steps followed to transform a Mondrian painting into an experimental stimulus (Figure 2a), and the resulting stimuli used in this study (Figure 2b). Each column in Figure 2b presents variations from the same stimulus: Golden ratio (GR), half ratio (1/2), and sixth ratio (1/6).

golden ratio version of the picture. Pictures with 1/2 ratio were obtained by displacing the vertical axis towards the middle of the figure. Pictures with 1/6 ratio were obtaining by displacing the vertical axis of the figure to either the left or the right until reaching 1/6 of the figure wideness (see Figure 2b).

In the experimental conditions each pair of paintings contained one golden ratio painting and one with a different proportion. In control conditions both paintings were identical, and one of them was defined as pseudo-golden beforehand. If golden ratio influences the perception of beauty then paintings presenting golden ratio should be preferred over paintings that present ratios of 1/2 or 1/6 in the experimental conditions, while no preference for pseudo-golden stimuli should be found in control conditions.

METHOD

Participants. Thirty-six undergraduate students of Psychology at the Universidad de Jaén participated in the Experiment. They were between 18 and 26 years-old (average age = 19.5 years), 75% of them were males and 25% were females. None of them had previous experience with the task. Students' participation was voluntary, allowing them to receive academic credit that could also be obtained by alternative activities.

Apparatus and Stimuli. The experiment was conducted on 5 Windows XP® based personal computers that were placed in 5 isolated cubicles. The task was implemented using SuperLab Pro 4.0.6 (Cedrus Co). This software allows for the design of experimental procedures involving the presentation of different stimuli on a computer screen and recording participants' input through either the mouse or a standard keyboard. All stimuli were displayed on 19" TFT computer screens.

The stimuli were three different versions of each of 5 original paintings of the Dutch painter Mondrian (golden, 1/2, and 1/6). The paintings are presented in Figure 2. The first row presents the 5 stimuli that kept the golden ratio (GR). The second row presents the same 5 stimuli modified to keep a 1/2 proportion. Finally, the third row presents the same 5 stimuli modified to keep a 1/6 proportion. To avoid confounds that could affect aesthetic preferences, color was eliminated from the original paintings, and they were modified according to the aesthetic model proposed by Deischer (2004). The choice of the specific variations of the paintings was done following the rules presented by Pisano with respect to the division of a line (Sigler, 2002) . Within the multiple possibilities, we

chose the golden ratio (GR), the 1/6 division, a proportion that has been implicitly or explicitly considered as no beautiful since the Ancient aesthetics, and the 1/2 proportion that is assumed to be monotonous (Tosto 1983).

Procedure. Participants were tested in groups of 5. They were randomly assigned to each computer upon their arrival to the laboratory and informed about the general features of the experiment. They were asked to read and sign a standard informed consent form before continuing with the experiment if that was their wish. Instructions were presented in 5 screens using a white font against a black background. At the bottom right corner of each screen the sentence "Press the spacebar to continue" was presented.

Practice Trials. There were 6 practice trials presented in two separate blocks. The first trial was preceded by the following instructions: "You will start with a PRACTICE TRIAL. You will see first the word 'loading…'; pay attention because there will appear two different Picasso paintings immediately afterwards. Your task consists on selecting which of the two paintings you consider the most beautiful by pressing the keys "C" or "M" to select the painting presented on the left or on the right, respectively. Please, call the experimenter before going on." Once participants called the experimenter, they were asked whether they had any doubts about what they were requested to do. Once doubts were resolved by the experimenter, participants were told to click on the "continue" button to go on into the first and second practice trial. Two Picasso paintings ("Girl in front of mirror" and "Three musicians") were presented together.

Once the participant made the choice between the two paintings, the second block of practice trials started with the following instructions: "Now you are going to have new PRACTICE TRIALS in which different paintings of well-known painters will be presented. You will have to give your answer in a similar way to what you did in the previous trial, paying attention when the instruction 'loading…' is on, and then pressing key C or key M to indicate which painting you consider more beautiful. From now on IT IS VERY IMPORTANT that you make a VERY QUICK choice, given that you only have A SECOND AND A HALF to CHOOSE the painting that you consider more beautiful. Call the experimenter before going on" –captions reflect how the words were actually presented on the screen. The experimenter resolved participants' doubts and reminded them that they were going to have 4 practice trials, and that they had only 1.5 s to make their choice.

The experimenter left the cubicle and participants started with the training, though cubicles doors remained open throughout the experiment (pilot studies had shown that full isolation lead some participants to lose motivation, responding randomly). The change from one trial to the following one occurred either when participants gave their choice or 1.5 s after paintings were presented, whatever took place first. Paintings used in these four practice trials were, "Girl in front of mirror", "Three musicians", "The Dream", and "Velazquez portrait".

Testing Trials. Immediately after the last practice trial, the following instructions appeared on the screen: "Practice trials have ended and you are about to start with the task in which we have selected new paintings of well-known painters. During the task you should proceed as you have done during the practice trials. It is possible that some of the paintings look the same to you; even in this case you have to select the one that you think it is more beautiful. REMEMBER: It is very important TO MAKE A QUICK CHOICE of the painting that you consider the most beautiful given that you only have A SECOND AND A HALF to give your choice. Call the experimenter before going on." After the experimenter solved any doubts participants may had about the task, he left the cubicle, and the proper task begun with the following instruction that was presented a single time: "Which painting do you think it is more beautiful?" The instruction remained on the screen for five seconds.

Test trials were presented without additional instructions afterwards and were identical to the practice trials, except for the stimuli used. Each trial involved a transition screen that defined the inter-trial interval, and the stimulus screen. The transition screen lasted for 500 ms. The message 'Loading…' was presented in the center of the screen with a little rectangle on top of this message. An additional rectangle was added to the first one every 100 ms. to give the impression that the trial was being charged. After the fifth rectangle, the transition screen was substituted by the stimulus screen. In each trial, two versions of the same painting (13.25 cm. tall x 8.2 cm. wide) were presented centered in the screen with a distance between them of 3 cm. For each of the 5 paintings presented in Figure 2 there were 10 different trial types, attending to all the possible combinations of versions GR, 1/2, and 1/6, and the position of each version (left or right). The 10 pairs of stimuli resulting of combining the 3 trial types (GR-1/2, GR-1/6, and C) and the position in which each stimulus appeared are presented in Table 1. In the control trials in which both paintings were the same, one of them was defined as pseudo-golden stimulus beforehand,

taking in account that in half of the trials with each painting the pseudo-golden version was the one on the right, while in the other half the pseudo-golden version was the one on the left. Note that each pair in which the two paintings were identical was repeated twice so that one of the two possible positions (left or hand) were defined as the pseudo-golden response beforehand. This distribution allowed for equating possible biases on responding between the experimental and control trials. Note that the within-subject design led to differential familiarity between the golden-ratio based stimuli and the alternative ones. This differential familiarity will be corrected in the between-subject design of Experiment 2.

The task involved eight 50-trial blocks. The 50 trials correspond to the different combinations presented in Table 1 for each of the 5 different paintings used in this experiment and presented in Figure 2.

Dependent variable and data analysis. The choice given by each participant was recorded in each trial. Proportion of GR choices was recorded for each painting and each participant in the three possible combinations, GR-1/2, GR-1/6 and Pseudo-Golden Control. Values over 50 indicate preference for the golden or pseudo-golden stimulus, depending on the trial. Proportions were analyzed by an analysis of variance (ANOVA) setting the rejection criterion at $p \leq .05$.

RESULTS

Figure 3 presents the mean proportion of GR choices for each type of trial (GR-1/2, GR-1/6 and Control). Proportion of GR choices was greater in GR-1/6 trials than in the other type of trials, suggesting a greater preference for GR stimuli when they were paired with 1/6 stimuli than when they were paired with the 1/2 stimulus, or in the control condition. A 3 (Trial-Type) x 5 (Painting) x 8 (Block) ANOVA only found a significant main effect of trial type, F (2, 70) = 4.10 (MSE = 12631.48, $p = 0.021$, $\eta^2 = 0.105$, $1\text{-}\beta = 0.71$). Focusing on the relevant pairwise comparisons the preference for golden ratio was significant when comparing GR-1/6 with C trials, F (1, 35) = 5.13 (MSE= 11059.88, $p = 0.03$, $\eta^2 = 0.128$, $1\text{-}\beta = 0.60$), but it was not significant when comparing GR-1/2 with C trials, F (1, 35) = 1.10 (MSE = 4280.71, $p = 0.30$, $\eta^2 = 0.03$, $1\text{-}\beta = 0.17$).

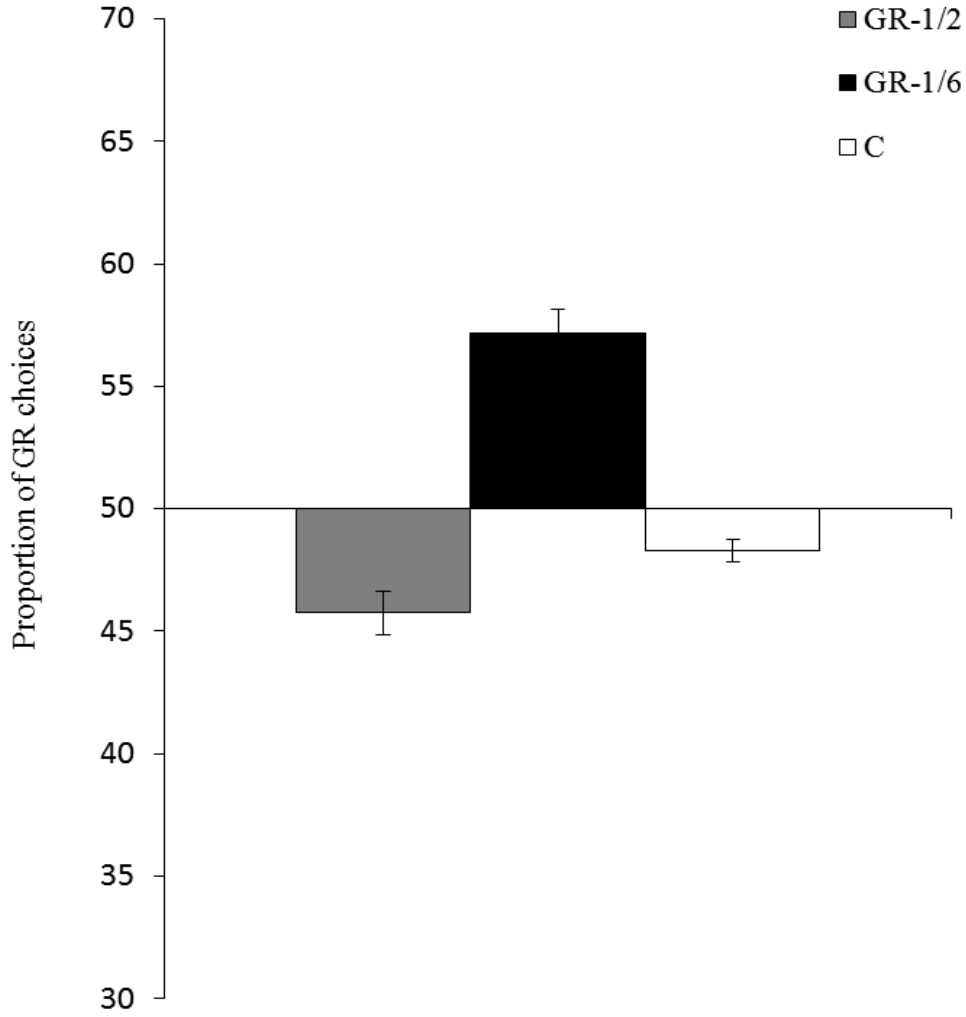

Figure 3. Proportion of Golden Ratio (GR) choices in Experiment 1 for each of the three types of tests (GR-1/2, GR-1/6 and C).

In summary, participants showed a preference for the version of the painting that kept the golden proportion over the one that maintained the proportion of 1/6. These results extend to complex artistic stimuli those reported in the literature using simple geometric figures (Fechner, 1876/1997; Eysenck, 1968; Lalo, 1908; Thorndike, 1917; Witmer, 1894). The lack of significant differences between the stimuli that kept the golden

proportion and the ones that kept the symmetry (1/2) could be indicating that small differences from golden proportion do not influence the aesthetic based preference. Alternatively, symmetry may also influence perception of beauty (Delvin, 1998; Ramachadran, 2008; Weyl, 1991).

However, before making any strong conclusion about the role of golden ratio on perception of beauty, it should be noted that the experimental design allows for an alternative explanation in more simple terms. Note that the within-subject design used in this experiment led to differential familiarity between the golden-ratio based stimuli and the others. Table 1 shows that GR stimuli are presented more times than the others with a proportion of 8 to 6. It could be argued that the preference for the GR stimuli is due to the greater familiarity of those stimuli with respect to the others, leading participants to choose the most repeated stimulus (Marty, 2002; Marty, Munar, & Nadal, 2005). Additionally, if participants would have had difficulties to differentiate between the golden-ratio stimulus and the 1/2 stimulus, presentations of this latter stimulus could have functionally increased such familiarity. Experiment 2 used a between-subject design with the goal of equating the familiarity across all the stimuli presented, allowing for testing the role of golden ratio on beauty perception without those confounds.

EXPERIMENT 2

The main goal of Experiment 2 was to test the golden-ratio based aesthetic preference in a situation in which the familiarity of all the stimuli involved in the task was the same. The experiment involved two different groups. In group 1/6 participants only received trials in which the golden-ratio variations were compared with the 1/6 ratio variations, while in group 1/2 the comparison variation was the 1/2 ratio version of the stimuli. Both groups included control conditions in which the two versions of the presented stimuli were the same. If preference for golden-ratio in Experiment 1 was due to differential familiarity of the stimuli, no preference should be observed in Experiment 2. However, if this preference is based on the golden proportion then GR stimuli should be preferred over 1/6 stimuli with respect to the control condition. According to the results obtained in Experiment 1, no differences were expected in the preference for the GR over the 1/2 stimuli with respect to the control.

METHOD

Participants. Sixty-eight undergraduate students of Psychology of the University of Jaén participated in the experiment. They were between 18 and 26 years-old (average age = 19.4 years); 75% of them were male and 25% were female. They had no previous experience with this task.

Apparatus and procedure. Apparatus and procedure were identical to the ones used in Experiment 1, except for what follows. Participants were randomly assigned to groups 1/6 or 1/2 upon their arrival to the laboratory. There were only 4 combinations of trials within each group (GR-1/X, 1/X-GR, GR-GR, and 1/X-1X in which the X represents the appropriate proportion for each group, 1/6 or 1/2 for groups 1/6 and 1/2, respectively). The task was arranged in 8 40-Trial blocks. Each trial combination was presented twice with each specific painting presented in Figure 2 within each block of trials.

RESULTS

Figure 4 presents the mean proportion of GR choices in groups 1/6 and 1/2. A 2 (Group) x 2 (Trial-Type) x 5 (Painting) x 8 (Block) ANOVA only found a significant two-way interaction, F (1, 65) = 5.06; MSE = 12411.01, $p = 0.028$, $\eta^2 = 0.072$, $1\text{-}\beta = 0.60$. Subsequent analyses conducted to explore the interaction found that the simple effect of Trial-Type was significant in group 1/6, F (1, 33) = 9.56, MSE = 18379.92, $p > 0.01$, $\eta^2 = 0.225$, $1\text{-}\beta = 0.85$, but it was not significant in group 1/2, $F < 1$. Proportion of GR choice was statistical greater in GR-1/6 trials than in control trials in group 1/6, while no differences appeared in group 1/2.

Once again, no differences in preference were found when golden-ratio based stimuli were compared with stimuli that kept a proportion of 1/2.

This experiment replicates the results obtained in Experiment 1 with respect to an aesthetic preference for the golden ratio based stimulus with respect to the one that kept the 1/6 proportion in a situation that could not be explained in terms of differential familiarity with the used stimuli.

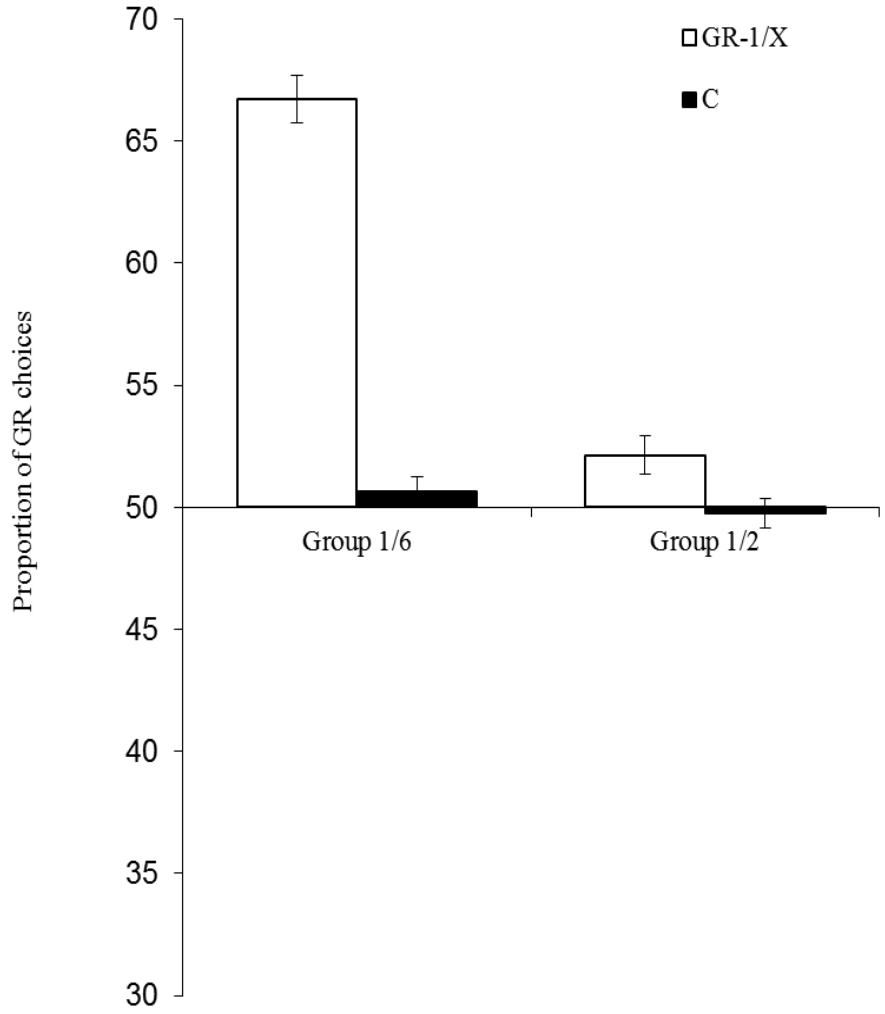

Figure 4. Proportion of Golden Ratio (GR) choices in Experiment 2 in each group (1/6 and 1/2). The value of 1/X corresponds to1/6 in group 1/6 and 1/2 in group1/2.

GENERAL DISCUSSION

The main goal of the experiments reported here was to study whether there is an aesthetic preference related to golden ratio. These experiments tested the hypothesis that stimuli that did keep the golden proportion should

be perceived as more beautiful than the stimuli that did not keep that proportion. Results seeme to support this idea. In Experiment 1, participants perceived as most beautiful the paintings disposed in a golden ratio compared with paintings that present a 1/6 proportion. This preference was replicated using a between-subject design in Experiment 2. However, no preference for golden ratio with respect to the 1/2 proportion was found in any of the experiments. So, the results obtained in these studies suggest that golden ratio may be one of the factors at the base of the aesthetic preferences of participants without formal arts training under some circumstances.

Throughout history different factors have been proposed as related to perception of beauty, such as complexity of the stimulus pattern, the order (e.g., Birkhoff, 1932), and also the golden section (Eysenck, 1968; Fechner, 1876; Lalo 1908; Thorndike 1917; Witmer, 1894). In agreement with related studies (e.g. Benjafield, 1976; Feasey, 1921; Gordon, 1929) in which golden ratio was studied with simple stimuli, or studies with more "natural" artistic stimuli (Konecni, 1997, 2001, 2003), the results found in the two experiments that conform this study support the idea that those pictorial stimuli that maintain their proportions according to the golden section are perceived as more beautiful than those stimuli in which such a proportion is heavily broken (1/6). Results reported here extend to abstract painting the results of studies that have systematically manipulated proportions of the human body in sculpture and photography (Di Dio, Canessa, Cappa and Rizzolatti, 2011; Dio, Macaluso and Rizzolatti, 2007). However, it should be pointed out that preference for familiarity and preference for golden proportion is confounded in those studies. As Doczi (1996) points out, the human body has proportions close to golden ratio so that familiarity with that proportion might have led participants to preferentially choose the golden proportion, more familiar images.

The lack of differences between the golden-ratio based stimuli and those stimuli that did keep a proportion of 1/2 could be reflecting either that symmetrical stimuli are perceived as beautiful as the stimuli that did keep the golden proportion (Delvin, 1998; Ramachadran, 2008; Weyl, 1991). Alternatively, in the situation designed here, with just 1.5 s to make the choice, participants may have had difficulties to perceive differences between the golden-ratio based stimuli and symmetrical stimuli.

Results also could be based on cultural preferences, rather than in unlearned psychological features. Exploring this issue, Berlyne (1970) conducted a cross-cultural study in which he compared the preferences of Canadian and Japanese high-school girls. He found that Japanese girls

preferred square-like rectangles while Canadians' preferences were closer to rectangles of golden proportion. Berlyne concluded that the preference for the golden ratio could be the result of cultural differences. As the use of golden section in arts has been commonly used for centuries within the Western Culture, members of Western societies may be inclined to consider golden section beautiful because they are used to encounter many instances of golden ratio in artistic works or industrial artifacts (Berlyne, 1971).

The designs used in this report cannot distinguish between cultural or perceptual explanations of the lack of differences between golden-ratio based stimuli and 1/2 based stimuli. However, this null result only limits conclusions with respect to perception of relative beautifulness when comparing symmetrical and golden-ratio based stimuli. Being conservative, the results of these experiments at least allow concluding that proportions around golden ratio are considered more beautiful than proportions around 1/6.

Once shown that golden section is aesthetically preferred by non-trained participants, an interesting question is why golden section could be aesthetically relevant. Stone and Collins (1965) proposed the perimetric hypothesis, suggesting that preference by golden section could be derived from some dimensions of our vision field. The starting point of this hypothesis was that human vision field defines a rectangle with an approximate ratio of 0.665, a value relatively close to golden ratio. Stone and Collins (1965) suggested that the aesthetic preference for rectangles with similar ratios to the golden number was based on the fact that there was an adaptation of vision to keep those ratio rectangles. Alternatively, Borissavlievitch (1958) points out that golden proportion contains the optimal proportion between similarity and difference, and that would be what it makes this proportion aesthetically likeable. Berlyne (1971) introduces the cultural factor suggesting that the preference for the golden section relies in the use of such a proportion in art and regular objects during centuries. At this point these hypotheses are speculative, and our results cannot favor or reject any of them. However, they offer some possibilities of additional research that should be explored in the future. For instance, the experimental method that we have developed in this report could be easily adapted to be applied to participants from different cultures, or with different artistic education as a way to extend the exploration of the role that golden proportion plays on aesthetic preferences.

In summary, many experimental results seem to uncover the existence of a universal criterion of beauty based on golden ratio; some of them suggest that this preference is innate while others reduce it to educational

and cultural factors. However, there are enough experimental results denying the relevance of golden ratio in perception of beauty as to casting doubts on its relevance. The question then is what the origin of these differences might be. We may only speculate at this point. Our suggestion is that the differences on perception of the role of golden ratio in art have their origin on the difference between real and ideal golden ratios. Real golden ratio is found in nature, while the ideal concept appears as a mathematical abstraction. Understanding this difference opens a way to analyze the dualism between beauty in nature and beauty in art, leading to retrieving a key concept on the history of art, *eurythmy*. The rupture with the *Great theory of beauty* may have its origin on a strict interpretation of the "harmony and proportion" rules. Analyzing the golden section as a growth pattern in nature, we will realize that measurements of the growth patterns of plants and many animals, including humans, are close approximations, but not the golden ratio itself (Doczy, 2004). In fact, classical artists initially sought in nature to find the source of beauty. They transferred the proportions of nature to their concept of art (including the golden section). Artists did this process by an intuition that was empirically acquired, rather than basing it on *a priori* scientific premises. It was only later when artists sought for a theory of beauty (Tatarkiewicz, 1989).

If perfection is in mathematics, why is it needed to adapt things to the human eye so that beauty is brought up? Mathematics gives an excellent approach, but it is not the key to beauty perception. This approach would give a solid support to classical *eurhythmy*. There may be a universal aesthetic preference for the golden section that is not based in mathematical reasons, but in the presence of little imperfections (Langlois, Ritter, Casey, & Sawin, 1995). This assumption opens the research to the exploration of tiny deviations from the canon of golden section in the artwork, comparing, for example, aesthetic preferences in well-known artists, like Mondrian, who follow the golden ratio with slight variations (organic model), with the same works strictly modified to fit golden ratio (mathematical model). Or comparing faces with axes near the golden section (organic model) with the same faces modified towards an exact golden ratio (mathematical model). Our hypothesis is that aesthetic preference will develop for the *organic* golden sections, so that small imperfections on the mathematical model increase perception of beauty. This is something that still should be empirically tested.

RESUMEN

Aproximación experimental al estudio de la belleza: El papel de la proporción áurea. En dos experimentos se evaluó el impacto de distintas desviaciones de la proporción áurea sobre la percepción de la belleza. Como estímulos se utilizaron adaptaciones en blanco y negro de pinturas de Mondrian ajustadas a la proporciones áurea, 1/6 y 1/2. En cada ensayo se presentaron a los participantes dos versiones del mismo estímulo. Los participantes dispusieron de 1500 ms para seleccionar el estímulo que consideraban más bello. En los ensayos experimentales una de las pinturas mantuvo la proporción áurea, mientras que la otra se ajustó a la proporción 1/2 ó 1/6. En los ensayos de control las proporciones de los estímulos fueron idénticas. Los participantes, estudiantes universitarios sin formación en arte, seleccionaron como más bellos los estímulos con proporción áurea en comparación con la proporción 1/6, pero no en comparación con la proporción 1/2. Estos resultados fueron consistentes tanto con un diseño intrasujeto (Experimento 1) como en un diseño entregrupos (Experimento 2).

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