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Influence of spatial imagery and imagery control on geometric form location in paintings

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A R T I C L E I N F O

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A B S T R A C T

The study of artistic works requires an educated vision, a certain way of looking that unveils potential relations amongst objects. Fine art students develop skills that are resultant of their training in finding possible connections amongst elements in a painting. One of the abilities related to the observation and analysis of a work of art is the capacity to form mental images. The present study involved 188 fine art students (105 first-year students and 83 fourth-year students) and was meant to find out whether their education level, their spatial imagery ability and their imagery control had any influence on the location of geometric forms in a painting. We assessed hits minus errors. Results showed Results showed that fine arts students' spatial ability and imagery control explained a significant percentage of score variation in the task of locating geometric figures in Velázquez's paintings. The significance of these results is consistent with those obtained in previous studies, spatial capacity, and imagery control influence on the achievement of skills in the artistic field.

1. Introduction

There are long-standing connections between geometry and art and artists have used knowledge from various fields to shape spaces in their canvases. During the Renaissance, painters tried to demonstrate their mastery of the visual arts by depicting polyhedra, sometimes very complicated ones (Martínez, 2010). When artists set themselves the goal of creating a faithful transposition of reality in their work, they had to investigate the laws of perspective, proportion and shape in order to render their compositions (for a review see Bouleau, 1996, Hernando-Pérez, 2012).

Bouleau (1996) took a trip down the history of painting with a focus on geometry and showed that different periods have their own particular geometry that allows for the composition of spaces. The author described how the flat surface of the painting acquires depth through different techniques, mostly geometry, colour, light and shadows. The compositions gain dynamism, movement, austerity, solemnity, balance, etc., depending on the theme and the artist's intention (Bouleau, 1996). An example of this is Vermeer (1632–1675), a humanist geometrician capable of playing with light and atmospheric density without the need for perspective to generate a sensation of depth. Also Caravaggio (1571–1610) who, with a dramaturgy of light, creates imaginary spaces full of geometries. Geometry is also found in the works of Velazquez (1599–1660), whose most well-known piece, Las Meninas (1656), was extensively reviewed not only by art historians or critics but also by mathematicians, who broke down the figures as rectangles,

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triangles and spirals built on the basis of the so-called Divine Proportion, or otherwise known as the Golden Ratio, Golden Number or Divine Number (Heras, 2015).

Recent experimental research has been focusing on aesthetic preferences for different geometric figures. McManus et al., (2010) confirmed participants' aesthetic preferences for rectangles, a fact already noticed in his previous work (McManus, 1980). Individual differences are not exclusive to rectangle preferences but can also be found in colour preferences (McManus et al., 1981), composition preferences (McManus & Weatherby, 1997), preferences for formal geometric patterns (Jacobsen, 2004) or preferences for particular types of triangles (Friedenberg, 2012). Although many studies have dealt with the influence of the golden ratio on perceived geometric beauty, no conclusive results have been reported. Stieger and Swami (2015) turned to explicit (i.e., conscious, deliberate) and implicit (eg., surveys) assessments to evaluate the preference for the golden ratio. The outcome did not reveal a clear-cut preference for this ratio over other ratios. According to the authors, a potential preference for the golden ratio does not seem to be automatically triggered and may rather be driven by artistic experiences.

With the intention of deepening our understanding of artistic practice, we consider whether the exploration of geometry in a painting can be a key to interpreting artwork as it is taught today in fine art schools. Undoubtedly, fine arts students develop skills that entail educating their eyes to observe, inter alia, all possible connections between elements in a painting. A skill related to the observation and analysis of an artistic work is the imagery ability. Meana (2000) speaks of three moments in creation: the moment of the object, the moment of the image and the moment of the work. The author, referring to the state of creation in the studio, assumes that relationships amongst things are established when the artist, in an initially unconscious way, generates associations between objects to reach a conscious image, somehow conferring order upon chaos. This order that arranges the relationships between objects is expected to be recognised by the viewer when standing before the work and his or her ability to envision those possible relationships may be the key to realising.

The experience of the artist as opposed to that of the amateur is shown in multiple studies (Koide et al., 2015; van Paasschen et al., 2015; Vogt & Magnussen, 2007; Zangemeister et al., 1995). Vogt and Magnussen (2007) compared artists with non-artists finding that the number of correctly remembered pictorial features was significantly higher in artists than in viewers without artistic experience. Professional art observers rely on more global viewing, especially when it comes to abstract images that require a greater visual effort versus non-professional viewers with a more local exploration of both realistic and abstract images (Zangemeister et al., 1995). Artists show a marked sensitivity to high-level characteristics such as texture and colour and therefore, their fixations are more driven by such features in comparison to novices (Koide et al., 2015). Additionally, art experts proved to rate higher than novices on aesthetic aspects (beauty and wanting) but no differences were found between groups on affective aspects (valence and arousal) (van Paasschen et al., 2015).

Also, the imagination facilitates multiple cognitive processes, especially creative work. Previous studies have emphasised that the imagery ability has an influence on different mental processes such as thinking (Campos & González, 2017), memorization (González, Goñi-Artola, & Campos, 2021), problem solving (Kunda, 2020) and creativity (Pérez-Fabello & Campos, 2011a, 2011b). Each academic degree stimulates specific skills necessary to acquire all the required competencies. Mastering these skills, being able to measure and improve them is a challenge in any degree program.

Visual imagery shares many of its mechanisms with visual perception (Kosslyn et al., 2001; Marks, 2022; Pearson et al., 2015). The skill to evoke particularly vivid and animated images could well be seen as a pivotal asset and potential source of inspiration for artistic production and perception (insight). Friedlander et al. (2022) consider image vividness in artistic creativity to lie in the individual's capacity to visualize the form, colour and texture of evoked objects with extreme clarity (Kozhevnikov et al., 2013). These skills seem to align with the view that artists perceive the world in a different way to non-artists, and indeed several aspects of their visual processing are key to their drawing talent (for a review see Chamberlain et al., 2019, 2021). This fact has been attested by previous scholars who bind mental object representations to drawings of those same objects (Matthews & Adams, 2008; Ostrofsky et al., 2015; J. 2016).

Floridou et al. (2022) analysed individual differences in mental imagery in different modalities and found that musical and video game experiences were connected to the frequency of involuntary musical imagery. Fine arts students have a high visual imaging ability as regards object features such as colour, form or brightness (Pérez-Fabello et al., 2014; M. J. 2016, 2018) and they report dissociative experiences related to absorption, fantasy proneness and imagination (Pérez-Fabello & Campos, 2011c). This propensity to dissociation sets them apart from other university students and is linked to creativity (Pérez-Fabello & Campos, 2011a, 2011b, 2022).

The present research aimed to find out whether the year the students are in (first or fourth), their spatial imagery ability and their imagery control had any influence on the location of geometric forms in a painting. To this end, the following were used as independent variables: school year, spatial imagery, and imagery control. The dependant variables were hits minus errors in locating geometric figures.

2. Method

2.1. Participants

The sample consisted of a total of 188 undergraduates, of which 148 were women, 105 from the first year and 83 from the fourth year, all coming from the Faculty of Fine Arts. The mean age was 20.53 years, (SD = 2.05), range 17 to 25. All students freely volunteered to participate in the study.

2.2. Materials

Three images of paintings by Diego Velázquez were used for training: Adoration of the kings (1619, Prado Museum: Madrid), The Forge of Vulcan (1630, Prado Museum: Madrid), and Three musicians (1617–1618, Gemäldegalerie: Berlin).

To assess the location of geometric figures in Velázquez's paintings, a test has been specifically tailored with five black and white copies of five of his paintings: Old woman frying eggs (1618, National Gallery of Scotland: Edinburgh), The Coronation of the Virgin (1641–1644, Prado Museum: Madrid), Christ in the house of Martha and Mary (1618, National Gallery: London), Lunch (1617–1618, Hermitage Museum: Saint Petersburg), The Surrender of Breda (1634–1635, Prado Museum: Madrid).

The Spanish version of the Measure of the Ability to Form Spatial Mental Imagery (MASMI: Campos, 2009, 2013) was used to measure the spatial imagery ability, especially the Visualization (VZ) factor. This test consists of a decomposed cube that individuals have to mentally recompose before answering 23 questions related to the said cube. Each test question has four possible answers, two are true and two are false. The total score of the test is obtained by adding the correct answers and subtracting the incorrect ones with results ranging from –46 to 46. Participants were allowed a period of 5 min to complete the test. The internal consistency of the MASMI, measured with Cronbach's alpha, was 0.93 (Campos, 2009). A Cronbach's alpha of 0.92 was obtained in this investigation. The MASMI test reliability was, according to the criteria of George and Mallery (2003), excellent.

The Spanish version (Pérez-Fabello & Campos, 2004) of the Gordon Test of Visual Imagery Control (Gordon Test: Richardson, 1969) was used as a measure of the imagery control ability. This test measures the participants' ability to control visual images and consists of 12 items in which individuals are asked to imagine a car in different colours, positions and states of motion. They must then rate each response on a 3-point scale ("no" = 0, "unsure" = 1, and "yes" = 2). The total score ranges from 0 to 24 points. High scores indicate better imagery control. Perez-Fabello and Campos (2004) obtained a Cronbach's alpha of 0.69. A Cronbach's alpha of 0.68 was obtained in this investigation. The reliability found in the Gordon Test is acceptable (George & Mallery, 2003).

2.3. Procedure

For the assessment of the responses to the geometric figures in Velázquez's paintings, the experimenters, authors of the work,

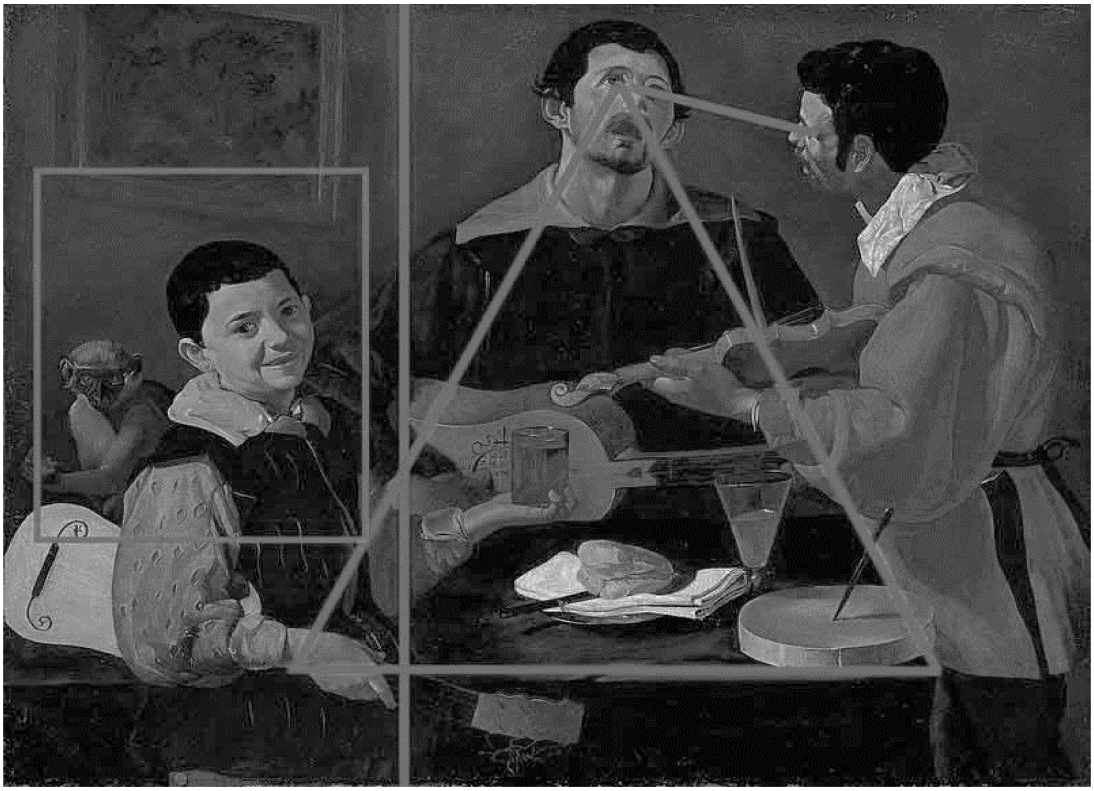

Fig. 1. Example of the Image of "Three Musicians" from the Painting by Diego Velázquez Used in the Training
Note. This example shows only some of the possible geometric figures found in the painting with the aim of keeping options open to participants. The explanations given were the following: If we draw a vertical line, we establish two spaces: one with the playing musicians and the other with a third musician and the monkey both looking towards the viewer. We can draw a triangle that comprises the still life and interrelates the characters. The gazes of the musicians intersect in an oblique line and even a triangle could be established containing the three characters. The square that links the monkey and the boy reinforces the structure involving the viewer.

together with an art expert, considered all possible responses to the five selected works. The geometric figures had to make sense in terms of the theme of the work or the author's intention. Each geometric figure (line, square, circle, triangle, rectangle, rhombus, etc.) that linked the characters in the painting, still life objects, looks, spaces, gestures, that is, that had a meaning or sense in the composition of the scene, was considered a success (see an example in Fig. 1). The formation of geometric figures guided by the shape of an object, for example, a circle on a plate or a head, a rectangle on a door, etc., was considered an error. It had been foreseen in the preparation of the test that, if there was an answer not previously contemplated by the experimenters and the art expert, it was to be considered an error, and in case of doubt it was consensual with the art expert. However, this situation did not occur eventually. Only the total score was used (hits minus errors) because both correct and incorrect answers are influenced by response thresholds (i.e., someone with a low response threshold will score higher on both correct and incorrect).

Participants, in their regular classrooms and in groups of about 20 students, were given a folder containing the test for geometric form location, the MASMI and the Gordon Test. This was followed by a training session that was carried out with images of Velázquez's paintings that were not included as part of the test. The training involved the projection on a screen of three images in full colour of three of his paintings that remained on the screen for the time necessary to explain some of the geometric forms that could be seen in the images. After that, the test began and the coloured images of the five illustrations were projected as a power point document using a projector. Each illustration remained on the screen for one minute. In that lapse of time, all participants had to draw on their black and white paper copy all the geometric figures they considered relevant. Once the image disappeared, the next one appeared and the participants proceeded to the next page of their black and white paper document, making it coincide with the one projected in colour, and so on, successively, until the end of the test. The total duration of this test was 5 min.

Once the geometric form location test was concluded, the students carried out the MASMI in order to measure their spatial imagery ability with a time limit of 5 min. Finally, they completed the Gordon Test to measure their imagery control ability with no time limit. Both these tests had their own written instructions. Students were guaranteed that their results would remain anonymous and confidential and written informed consent was obtained from each participant. The study was conducted in accordance with the ethical standards contained in the 2013 Declaration of Helsinki and was approved by the ethics committee of the University where the study was conducted (report no.: 0002-F-2022-03-25).

2.4. Data analysis

Statistical analysis was performed using the IBM SPSS Statistics, Version 25.0, statistical software (IBM Corporation, Armonk, NY, USA). The internal consistency of the tests was calculated by the Cronbach's alpha. We carried out a Linear Regression Analysis in order to spot relationships between the independent variables school year (first and fourth), spatial imagery ability (MASMI) and imagery control ability (Gordon Test) and the dependant variable score on correct hits minus errors in the task of locating geometric figures.

3. Results

The means and standard deviations of the different variables can be found in Fig. 2.

Results of the Linear Regression Analysis showed that image control (Gordon Test) and spatial image ability (MASMI) are in the final equation accounting for a 11% of the variance in the score on hits minus errors in the task of locating geometric figures. The independent variable school year was not significant (Table 1).

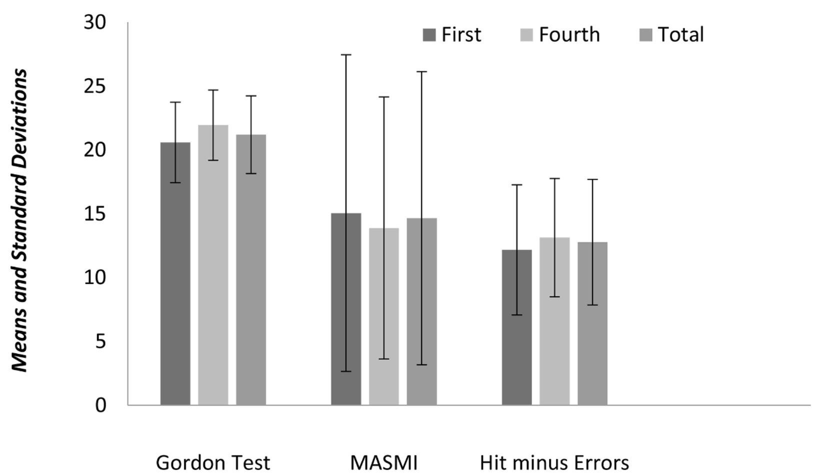

Fig. 2. Means and standard deviations of imagery control ability (Gordon Test), spatial ability (MASMI) and Hits minus errors as a function of school year.

Table 1
Linear Regression Analysis with Hits Minus Errors as Dependent Variable

R .33	$R^2 = .11$	*B*	*t*	*p*
Variables in the Final Equation				
Gordon Test		.26	3.51	.001
MASMI		.19	2.63	.01
School Year		.06	0.82	.41

4. Discussion

Results showed that spatial ability (MASMI) is influences in the execution of the task of finding geometric figures in Velázquez's paintings. The explained variance was low but significant. Campos-Juanatey, Pérez-Fabello, and Campos (2018) conducted a study where the ability to mentally rotate objects through the MRT (Wandenber & Kuse, 1978) was evaluated. The authors took into account the type of experience in spatial ability, comparing architecture, fine arts, psychology and business study undergraduates. When they rated the number of hits or hits minus errors, architecture students, followed by fine arts students, obtained significantly higher scores than students from the other majors. In addition, the importance of spatial ability has been demonstrated in the fulfilment of diverse kinds of activities such as the representation of a building through a blueprint (Campos-Juanatey & Campos, 2019), learning about a space through a map (Meneghetti et al., 2011) or spatial orientation on a map (Campos-Juanatey et al., 2021). In all cases it was found that individuals high in imagery scored higher on spatial tasks than those individuals low in imagery. Broadly speaking, visuospatial cognitive skills play a crucial role in explaining the accuracy of spatial mental representations (e.g., Allen et al., 1996; Fields & Shelton, 2006; Hegarty et al., 2006), and it has even been proven how teachers' spatial skills have an influence on their use of spatial teaching practices (Rocha et al., 2022).

The image control ability also proved to be significant in the task of finding geometric figures in Velázquez's paintings. Previous studies highlighted the implication of imagery control in both artistic activity (Pérez-Fabello et al., 2014) and academic performance (Pérez-Fabello et al., 2007). Pérez-Fabello et al. (2014) found that students high in imagery control scored better on spatial analysis and formal construction of an artwork than students low in imagery control.

The school year did not exert any influence on the results of hits minus errors in the geometric figures task. We therefore assume that a two-year time span in the education of experts and novices may not be enough to assess the influence of experience in the artistic field. In fact, previous work has been carried out with groups of artists as experts, and non-artists as novices (Koide et al., 2015; van Paasschen et al., 2015; Vogt & Magnussen, 2007; Zangemeister et al., 1995). Also, Ballesteros and García (1995) point out that experts in a given field concentrate more on the correct answers when solving problems and avoid wasting time on the wrong ones, their path is linear, and their behaviour is not as arbitrary as that of beginners. Several studies analyse the differences between experts and beginners in a skill (see, Starkes & Ericsson, 2003), as is the case of Chi et al. (1988) who, when referring to differences in performance, indicate that experts are faster and apply their skills with less chance of error than beginners.

4.1. Limitations and future research

The strength of this study is the novelty of an exercise specifically designed to assess a competence related to art education as well as its relationship with the students' level of studies and imagery skills. The results of this study are indisputable and are in line with previous research carried out with fine arts students; nonetheless, this study has some limitations. In the first place, the majority of participants are women thus limiting the outcome. In addition, given the lack of previous work with geometry in art, it is necessary to take the research further with a larger sample of fine arts students in order to strengthen the results. It would be interesting to replicate the testing in other degrees to see if spatial ability and imagery control exert any influence on the results of this exercise when performed by other types of undergraduates and even compare them with the results obtained by fine arts students. The research can also be carried out with high school students from the fields of arts, social sciences and science.

5. Conclusión

Undoubtedly, fine art students need to develop skills that allow them to reflect on the key aspects of artistic composition. In this study it was confirmed that spatial ability and imagery control are effective tools for student-artists to achieve skills in the artistic field.

Authorship statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in the Thinking Skills and Creativity.

CRediT authorship contribution statement

María José Pérez-Fabello: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Alfredo Campos:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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