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ColorDoku 3d, gamification to improve perceptual color discrimination ability and spatial vision

Juan Serra ^{1,*}, David de Andrés ² and Ana Torres ²

¹ Grupo de Investigación de Color en Arquitectura, Instituto de Restauración del Patrimonio, Universitat Politècnica de València; juanserra@ega.upv.es atorresb@ega.upv.es

² ITACA, Universitat Politècnica de València; ddandres@disca.upv.es

* Corresponding author: juanserra@ega.upv.es

Abstract

The description of color as a visual phenomenon with three perceptual variables, hue, value and saturation, resulted in different 3D color models since the beginning of the XIXth century. The ability to discriminate colors and organize them in the right order is a worth training for architects and artists, as it improves their sensitivity and expands their color abilities. Moreover, to have a robust spatial imagination is an essential skill for an architect, and so it is the understanding and manipulation of 3d objects. To merge the knowledge about regular polyhedra and color understanding, we have developed a digital app called ColorDoku 3d, in which the user can drag and drop the colors provided into the right faces of a solid to complete a 3d puzzle. This app is aligned with innovative pedagogical practices like gamification, that has demonstrated to be a good way to engage students in tough learning.

Keywords: architecture, geometry, color order system, gamification, puzzle

INTRODUCTION

In the acquisition of skills to work with the color for an architect or an interior designer, it is important to train the visual discrimination of colors and to gain the sensitivity to display different colors in order. Both learnings are on the roots of the different color curricula in the architecture schools since the beginning of the XXth Century and are considered essential knowledge. Gamification demonstrates to be a good way of involving students in the acquisition of these skills that not only need a rational understanding of color theory, but also need to be naturally integrated as an instinctive skill, something that happens after a dedicated training. Digital color puzzles are good alternatives to train these abilities but it is noteworthy that, despite having color three perceptual variables, most of the available color puzzles keep working with just two dimensions of color. For this reason, we have developed a new app called ColorDoku 3d, to ease the understanding that color has three perceptual variables and to train the visual discrimination of these variables. The app also gives the opportunity to get familiar with interesting and difficult to understand polyhedron.

THE TEACHING OF COLOR ORDER SYSTEMS IN ARCHITECTURE CURRICULA

The description of color as a visual phenomenon with three perceptual variables, hue, value and saturation, allowed the proposition of different three-dimensional models since the beginning of the XIXth century, with different shapes depending on the arrangement of the fundamental colors and specific nomenclatures for the variables (Nemcsis and Caivano 2015).

The ability to discriminate colors and organize them in the right order is a worth training for architects and artists, as it improves their sensitivity and expands their color abilities. For these reasons, almost all the modern color curricula for architects included the study of color circles and other similar organizations of colors with a certain logic (Hirschler et al. 2018). This was also the case of the basic courses at the *Bauhaus Dessau* and the *Hochschule für Gestaltung Ulm*, with important academics such as Albers, Itten, Maldonado, etc. (Campos and Moya 2021). In recent years, some of

ColorDoku 3d, gamification to improve perceptual color discrimination ability and spatial vision

the traditional color exercises shifted into a digital version, as it happened with the perennial *Interaction of Color* by Joseph Albers (Franco Taboada 2015). Nevertheless, some of these traditional exercises need personal involvement, are time-consuming, and not always are easy for generations of students and professionals that are becoming more impatient and less persistent (Bauman 2015). At the same time, in a completely digitalized society, gamification gives an opportunity to improve the color skills, and the pleasure of organizing colors in order is on the roots of a big number of digital games: *Blendoku* (Lonely Few 2015), *Tinge* (Suwao LLC 2019), *Chroma* (Noisy Duck 2021) and *Chroma Rush* (Lonely Few 2017). As indicated, all these apps have a two-dimensional interface and forget that color is a three dimensional perceptual phenomenon (Figure 1).

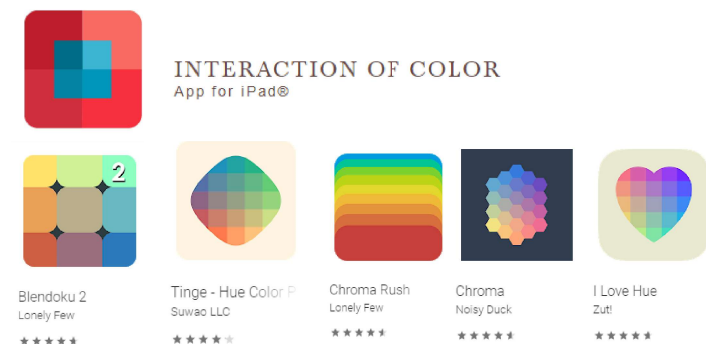


Figure 1: Icons of some popular color Apps. The first one, Interaction of Color, is a digital version of the traditional exercises of J. Albers in a digital way.

THE TEACHING OF REGULAR BODIES IN ARCHITECTURE CURRICULA

To have a robust spatial imagination is an essential skill for an architect, and so it is the understanding and manipulation of three-dimensional objects. If we review the European history of architecture, this ability has traditionally been cultivated with the study of regular polyhedra with complex geometries that we find since the most important treatises of geometry belonging to the Renaissance period until today. This is the case of *De Divina Proportione* (1509) written by the mathematician Luca Pacioli and illustrated by Leonardo da Vinci, who used the most cutting edged graphic resources of that period to help in the understanding of the geometries, with skeletal solids that allowed an easy distinction between front and back edges (Figure 2a).

In the XIXth century, the color was also used as a graphic resource for a better understanding of geometry. This is the case of the founding text of geometry *The Elements* (Στοιχεῖα) written by Euclides (325-265 bC), that was reedited by Oliver Byrne in 1847 with graphical codes of colors replacing the original text (Higón-Calvet 2013). The combination of colors and geometry resulted in a very beautiful and easy to understand publication (Figure 2b). Nowadays, the videos and animated graphics with continuous movement seem to be the most adequate means of expression to explain and understand complex geometries.¹

¹ <http://www.matematicasvisuales.com/index.html>

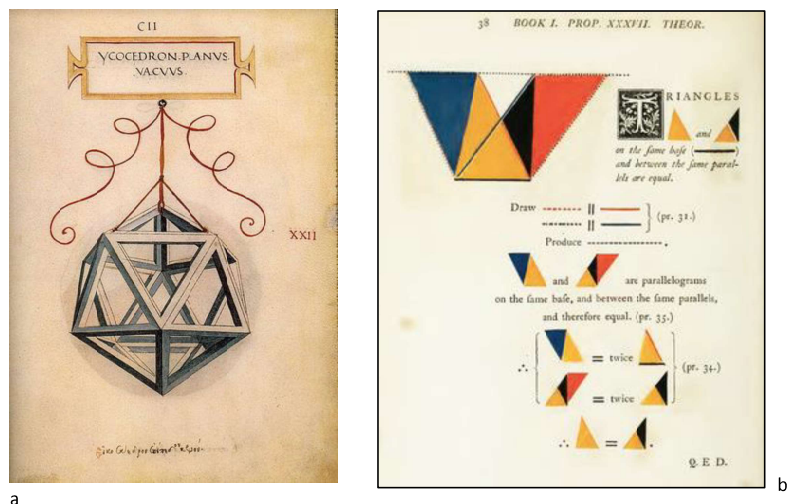


Figure 2: a) Representation of an icosahedron, *Ycacedron Planus Vacuus*, by Leonardo da Vinci for *De Divina Proportione* (Luca Pacioli 1509); b) Oliver Byrne, *The First Six Book of the Elements of Euclid*, London, 1847. Book I Prop. XXXVII "Triangles on the same base and between the same parallels are equal".

DESCRIPTION OF THE APP COLORDOKU 3D

To merge the knowledge about regular bodies and color understanding, we have developed a digital app called ColorDoku 3d that is available for free at the web page of the Color Research Group in Architecture UPV². By the moment, it contains four regular solids with triangular faces: icosahedron (20 triangular faces), triacysthetrahedron (12 triangular faces), tetrahexahedron (24 triangular faces) and hexakisoctahedron (48 triangular faces) (Figure 2). The icosahedron is a polyhedron that belongs to the Platonic solids, and has been widely represented and used since antiquity. The other three polyhedra belong to the family of Catalan solids, after the Belgian mathematician Eugène Charles Catalan. These polyhedra are generated with two Archimedes solids, and so their faces have irregular polygons but equal dihedral angles: the triacysthetrahedron is a truncated tetrahedron, the tetrahexahedron is a truncated octahedron and the hexakisoctahedron is a truncated cuboctahedron.

In the initial screen of the app, users can choose between the four aforementioned polyhedra, and set different parameters depending on the expected level of difficulty for the game, such as the scale of the solid, its position inside the color space, and the number of faces of the figure that will appear with the colors already set. With this information, a color palette is displayed and the 3d puzzle is launched. Turning the figure round in any direction and increasing its size if needed, users can drag and drop the colors provided in the color palette into the right faces of the solid to complete the 3d puzzle.

² https://grupocolor.webs.upv.es/?page_id=3275

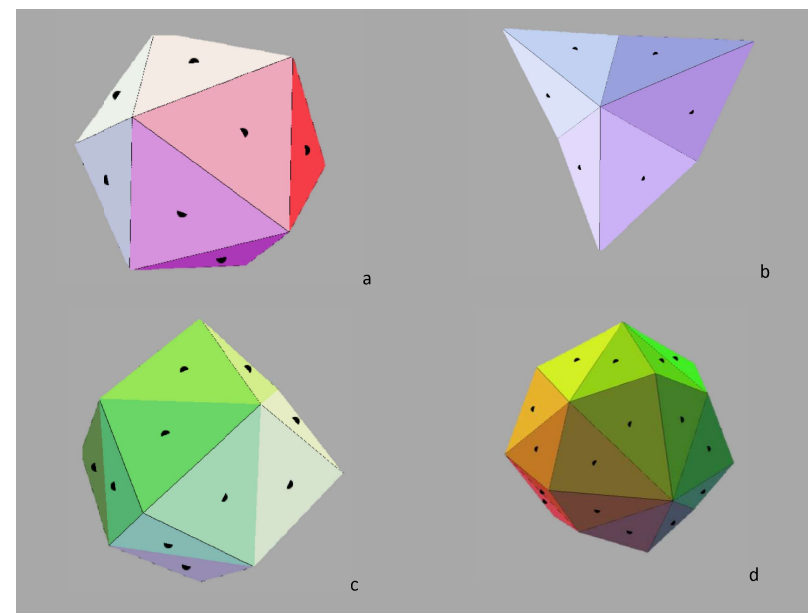


Figure 3: The four regular bodies implemented in ColorDoku 3d: a) icosahedron, b) triacysthetrahedron, c) tetrahexahedron and d) hexakisoctahedron.

In the screen of the settings, and when the scale of the regular body is under 100%, it is possible to place it in different positions inside a virtual cube (Figure 4). This cube represents the color space HSL (Hue, Saturation, lightness), which is an alternative model to RGB, and therefore a useful color space for digital displays. When the user selects different values between 0% and 100% for the three spatial directions X, Y and Z, is placing the solid in a different position into the HSL space. The app will automatically generate a color palette assigning to each triangular face of the solid the color corresponding to the barycenter of such a face in the HSL model.

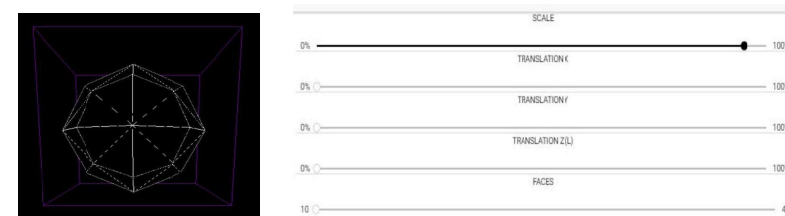


Figure 4: Aspect of the screen for the puzzle settings with indication of the variables to set: scale, translation X, translation Y, Translation Z and faces.

When the 3d puzzle is launched, the interface is divided in two parts. On the left side there is a color palette with all the colors of the puzzle in a random order and on the right side the user can rotate and scale the solid. Those colors preset have a grey cross on the color palette and a black dot on the corresponding face to indicate that they are locked. The rest of the colors in the color palette can be dragged and dropped onto the corresponding face. With the help of an eraser, the user can remove a color placed in a wrong position that will automatically move back to the color palette. When the 3d puzzle is correctly completed the indication “puzzle completed” appears.

We hope that this new app will help to improve at the same time the perceptual color discrimination ability together with the spatial vision.

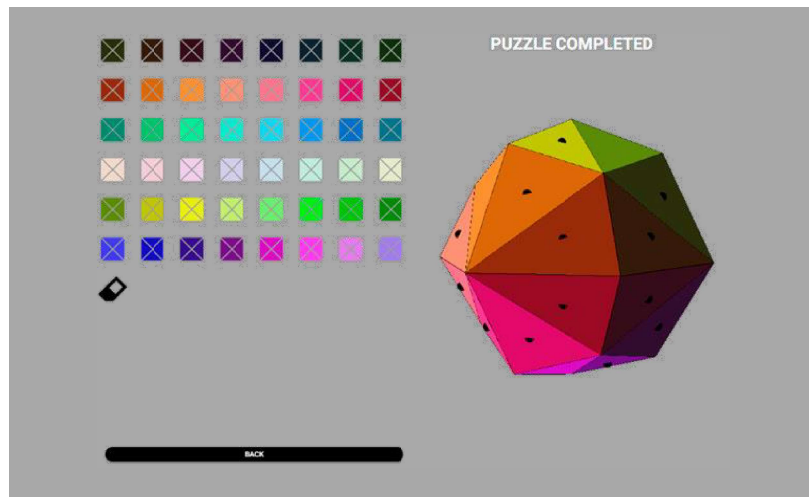


Figure 5: Interface of ColorDoku 3d with a completed puzzle of an hexakisoctahedron.

RESULTS AND CONCLUSIONS

In the course 2020/21 we invited the students enrolled in the subject Graphic and Chromatic Design of the Master in Architecture of the UPV to train with ColorDoku 3d and give their opinion. A total of 18 students (12 females, 6 males; Mean age= 23) played with the app for a couple of days and gave a feedback via an online questionnaire. Regarding the selection of the polyhedra, icosahedron was the most selected (50%), followed by tetrahexahedron (27.8%), hexakisoctahedron (16.7%) and triacysthetrahedron (5.6%), therefore the selection of the polyhedra seemed to be rooted in a personal attachment and not in the number of faces of the solid or its difficulty. According to the answers, 33.3% of the respondents considered the random colors combination provided beautiful, 22.2% not beautiful and 44.4% indifferent. Considering the difficulty of the 3d puzzle, 44.4% considered it easy, 33.3% intermediate and 21.7% difficult or very difficult, with this assessment dependent on the puzzle settings of each participant. In an informal interview in the classroom, students expressed their interest in the app, indicating that it was fun and engaging, but also pointing out some aspects to improve, particularly related with the interface and the general user-friendliness of the app. Students seemed to be in favor of having an automatic preset of the parameter of the puzzle.

We conclude that ColorDoku 3d is a useful tool for the education of students in the improvement of their perceptual color discrimination ability and spatial vision, being a complementary resource to train their color abilities out of the classroom via gamification. In the future, the app will need some upgrades to make it more user-friendly and engaging, taking into account the information provided by a target group of users.

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