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Finding Patterns in the Location of Elements to Increase Readability

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ABSTRACT: There are many times when visuals and text will often disrupt each other in a single space and, as a result, make both more difficult to understand. Many methods exist to counteract this, such as placing text and visuals in specific locations in the given space. We have utilized these certain "combinations" to a great extent. Still, when there are special cases where these methods are less effective, finding an optimal combination as a replacement is more difficult. To see other patterns and techniques to assist in locating salient elements, we can use game theory and graph theory, as well as a small amount of cognitive neuroscience, to determine what combinations allow words and visuals to complement each other rather than compete. The research done in this paper is exemplified by bento grids, a recent design trend popularized by Apple.

KEYWORDS: Systems Software, Game Theory, Shapley Values, Saliency, Grid and Place Cells, Cognitive Neuroscience, Bento Grids.

Introduction

The bento grid is a design trend that promotes simplicity and easy comprehension by grouping information and graphics into boxes along a grid – like the bento boxes they refer to. The design trend became extremely popular in 2024, partly due to Apple using the format in their product summaries. A poster is a plane that is usually occupied by both graphical and typographical elements. To best utilize the space given, designers will often put text and visuals close together in specific locations so that if a person reads it, they can understand what is shown quickly and efficiently, just like in bento grids.

("Bento grid" by @bymyno_)

The question is, what sort of combinations are optimal for making posters coherent? There are certain combinations of text and visuals that, if positioned correctly, can make the information easier to read and understand. While there are many important factors to creating an effective and readable poster, such as color, content, and format, a factor that is less often discussed is the locations of the given elements. A lack of understanding of these concepts and what makes them behave the way they do can lead to misinformation, disinterest, lack of clarity, or lack of appeal. An example is a cluttered website with no clear direction for the user to follow, leading to confusion.[1]

Saliency is a factor that describes how "important" something is to your eyes and how much attention it will attract. The color red, for example, increases the saliency of an object; so do size and contrast. In our example, position can also increase or decrease the saliency of an object. The focus is to make important information salient and let other information be less so by changing the position of the elements.[2]

Additionally, grid and place cells play a role in spatial navigation when an individual moves within an environment. Recent studies have implied that these cells within the brain also respond to the movement of one's eyes.[3] Since visual stimulus is one of the key inputs to the brain's navigation system, it should impact the process of locating salient text and other attention-grabbing elements.

Game theory involves the mathematical analysis of strategies in both competitive and cooperative scenarios; we can utilize this in a "cooperative scenario" by using Shapley values, which determine how each value "contributes" to a given whole.[4,5]

Graph theory involves using graphs made up of points called vertices and connecting lines called edges; these graphs, with the data they contain, are then analyzed and used to draw conclusions. We can utilize this in the form of centrality. In graph theory, Centrality determines the "importance" of a particular vertex based on different factors, such as the number of edges it is connected to or the number of paths that pass through it.[6]

Using a custom program, we can collect data by creating various scenarios for participants. Then, we can apply Shapley values and centrality to the data to determine in what positions elements are most salient and how to make the most important information contribute the most.

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Methods

In this paper, we create a program in Scratch, a program that will display preset combinations of letters A-E on a 4x4 grid and then ask participants to find the letter A, as shown in Figure 1.

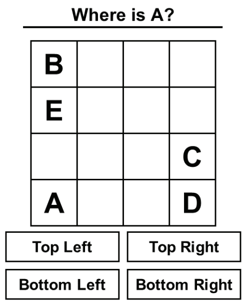

Figure 1: An example of a grid given to the participants to determine which location of A leads to the shortest reaction time.

There are many different combinations of where the letter A is placed, such as the quadrant it is located in:

- Top Left (**TL**)
- Top Right (**TR**)
- Bottom Left (**BL**)
- Bottom Right (**BR**)

There are also other factors, such as:

- Whether A is grouped (**G**) or standalone (**SA**)
- Whether the letters are located in the two center columns (**C**)
- Whether all the letters are normal - reading from left-right, top-bottom (**N**).

The program will then track how long it takes a person to find the letter. Once all the data is collected, we can make a basic assumption of which positions and combinations are optimal for the elements using the baseline data and then use data mining software that can utilize methods of finding Shapley values[4] to determine how important each position on the grid is.

The letter A represents an important element that needs to be more salient than the other letters. Prior research indicates that increased saliency can come in (but is not limited to) the form of position, color, or size. In theory, the combination of placements that results in the participant clicking on letter A in the least amount of time will be the combination that allows A to be the most salient and, therefore, works the best. Shapley values and centrality will be used to confirm these predictions further.

The independent variable in this experiment is the changes in position for the letters, and the dependent variable is the time, in seconds, that it takes for the participants to react and select an answer.

The first combination acts as a "control" by putting the elements in the most standard format - from top to bottom and from left to right; this combination is normal, grouped, and primarily organized in the top-left region. The grid is shown in Figure 2.

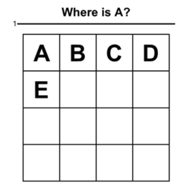

Figure 2: Combination #1; (TL, G, N) – Tests the response time for a "standard reading" format.

The second combination has A positioned in the bottom left quadrant of the grid, with no other letters; this is a test to see if an element is better standalone rather than grouped while also seeing if the bottom left quadrant holds better results than any other quadrants. The grid is shown in Figure 3.

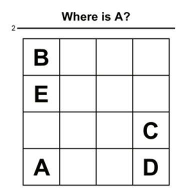

Figure 3: Combination #2; (BL, SA) – Tests the response time for a grid with A located in the bottom left, standalone.

The third combination has A positioned in the bottom right quadrant of the grid and is grouped with other letters; this determines if the bottom right quadrant holds better results than any other quadrants and compares grouped with any other ungrouped combinations. The grid is shown in Figure 4.

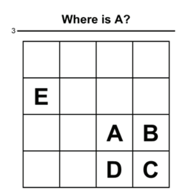

Figure 4: Combination #3; (BR-C, G) – Tests the response time for a grid with A grouped up in the bottom-right of the center.

The fourth combination has A positioned in the bottom right quadrant, with all the other elements grouped along the right quadrants. Similar to combination #3, this combination tests when the elements are grouped up in the bottom right but with other elements in different locations. The grid is shown in Figure 5.

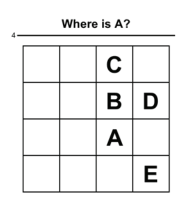

Figure 5: Combination #4; (BR-C, G) - Tests the response time for a grid with A located in the bottom-right of the center, with a more spread-out grouping.

The fifth combination has A positioned in the bottom left quadrant, primarily standalone. This combination is similar to combination #2, which tests whether a grid is better organized in the standalone, bottom-left format. The grid is shown in Figure 6.

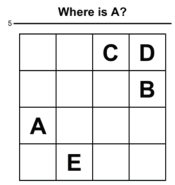

Figure 6: Combination #5; (BL, SA) – Tests the response time for a grid with A located in the bottom left, standalone.

The sixth combination has A positioned in the top left quadrant of the grid. This combination is similar to combination #1 but instead puts all other elements on other quadrants. The grid is shown in Figure 7.

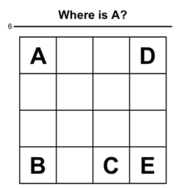

Figure 7: Combination #6; (TL, SA) – Tests the response time for a grid with A located in the top left, ungrouped, with all other characters located in other quadrants.

The seventh combination has A positioned in the bottom left quadrant of the grid, in the center columns, grouped with other letters; this is a test to see if an element is better if it is located in the center rather than on the sides, and, once again, testing grouped combinations with ungrouped ones. The grid is shown in Figure 8.

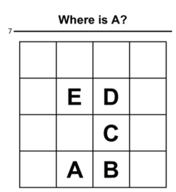

Figure 8: Combination #7; (BL-C, G) Tests the response time for a grid with A located in the bottom left, standalone.

The eighth combination has A positioned in the top right quadrant of the grid, with other letters lined up from right-left; this is a variation of the first combination, having a somewhat "normal" format. This is shown in Figure 9.

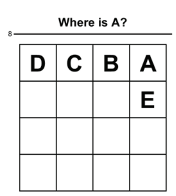

Figure 9: Combination #8; (TR, G, "N") – Tests the response time for "reversed reading" format.

The ninth combination has A positioned in the top left quadrant of the grid in the center column, grouped with the other letters. This tests to see if another combination of grouped-and-in-the-center-column is better than grouped and not centered. The grid is shown in Figure 10.

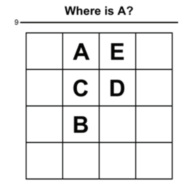

Figure 10: Combination #9; (TL-C, G) – Tests the response time for a grid with A grouped up in the top-left of the center.

The tenth and final combination has A positioned in the bottom right quadrant of the grid, with all other letters grouped in the bottom quadrants; similar to combination #4, it tests grouped up elements with A in the bottom right, but this time puts the other elements in the same horizontal quadrants, rather than the same vertical quadrants. The grid is shown in Figure 11.

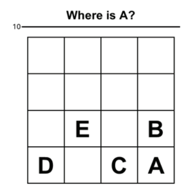

Figure 11: Combination #10; (BR, G) – Tests the response time for a grid with A located in the bottom right, with a more spread-out grouping.

Once all the data is collected, it is "codified" by making each factor identifiable by either 0 or 1. This is shown in Figure 12. It is then deposited into Orange 3, a data mining software that can be used to visualize Shapley values.

	top/bottom (0/1)	left/right (0/1)	center or not (1/0)	standard or not (1/0)	cluster or not (1/0)
Q1 (Control) Top Left, Standard	0	0	0	1	1
Q2 Bottom Left, Standalone	1	0	0	0	0
Q3 Bottom Right, Grouped	1	1	0	0	1
Q4 Bottom Right, Grouped (2)	1	1	0	0	1
Q5 Bottom Left, Standalone (2)	1	0	0	0	0
Q6 Top Left, Standalone	0	0	0	0	0
Q7 Bottom Left-Center	1	0	1	0	1
Q8 Top Right, Standard	0	1	0	1	1
Q9 Top Left-Center, Grouped	0	0	1	0	1
Q10 Bottom Right, Grouped	1	1	0	0	1

Figure 12: "Codifying" the data to input to Orange 3 for data analysis.

Using Orange, we can rely on multiple models to find Shapley values - although we will mainly focus on a model called linear regression. We can then look at the results very quickly in the form of a slope. The horizontal axis represents a factor of an element (e.g., located in the center or not), and the vertical axis represents the time spent (e.g., less or more time). So, the value on the horizontal axis with the lowest corresponding value on the vertical axis contributes the most to a more salient, important element. This can be used to create claims that will be accurate to the data.

To apply mathematical and scientific reasoning to the results of the participant data, we utilized a neural network on Google Colab that could simulate grid and place cells. Lambda, in the context of a grid-and-place cell network, is the distance between the nodes of the firing field of grid cells, while the filled

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percentage is the portion of the environment covered by the firing field of the grid cells. By adjusting the lambda (explains center or not) to get a loss function and the filled percentage (explains cluster or not) to get a mean absolute error, we can reproduce the results from the first experiment, and verify that our participant data is correct, while also gaining a logical reason as to why.

Result and Discussion

Results:

Figure 13 lists the times, in seconds, given by all 14 participants. The shortest time for each participant is highlighted in gray.

	Q1 (Control) Top Left, Standard	Q2 Bottom Left, Standalone	Q3 Bottom Right, Grouped	Q4 Bottom Right, Grouped (2)	Q5 Bottom Left, Standalone (2)	Q6 Top Left, Standalone	Q7 Bottom Left-Center, Grouped	Q8 Top Right, Standard	Q9 Left-Center, Grouped	Q10 Bottom Right, Grouped (2)
Trial 1	2.472	2.578	1.872	2.727	2.103	1.970	2.271	2.271	2.377	2.500
Trial 2	3.433	3.310	4.247	2.485	3.150	1.345	1.533	1.533	1.336	2.362
Trial 3	6.029	2.747	3.291	2.147	2.147	1.610	1.483	1.483	1.883	1.347
Trial 4	6.500	3.500	4.851	4.857	2.435	2.472	6.202	6.202	2.304	1.987
Trial 5	7.951	10.425	5.381	5.665	2.904	2.483	4.483	4.483	0.893	1.016
Trial 6	1.814	1.839	5.800	6.265	3.104	1.479	2.763	2.763	2.006	1.647
Trial 7	3.463	3.240	3.496	3.494	3.232	2.640	2.178	2.178	3.104	4.456
Trial 8	3.831	4.274	12.440	15.882	2.111	2.350	5.095	5.095	4.388	2.471
Trial 9	1.912	1.912	2.306	1.938	1.437	1.137	1.712	1.171	1.065	0.829
Trial 10	4.727	4.727	3.874	4.423	3.135	1.347	2.211	2.211	3.127	3.005
Trial 11	1.487	2.640	4.127	5.778	2.604	2.647	2.372	4.713	2.988	1.911
Trial 12	8.519	5.574	3.105	3.452	1.448	1.448	4.460	1.485	1.317	1.453
Trial 13	1.907	1.445	2.045	1.543	2.608	2.217	2.408	1.580	1.445	1.325
Trial 14	7.763	5.702	5.160	4.279	3.132	3.874	3.428	4.152	5.241	7.194
Average	4.415	3.851	4.428	4.619	2.539	2.073	3.043	2.951	2.391	2.393

Figure 13: The response time for each scenario (in seconds) from the participants.

When looking at the slope to determine whether the important element is on the top (0) or the bottom (1), we can see that if an element is on top, it contributes to a lower time, as shown in Figure 14.

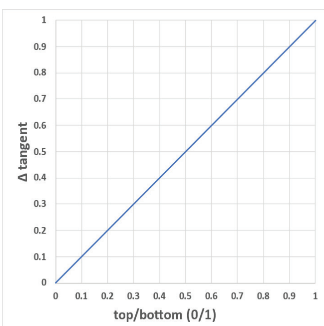

Figure 14: Top (0) or Bottom (1) – In most scenarios, the important element being located on the top of a space will contribute to a lower time.

When looking at the slope to determine whether the important element is on the left (0) or right (1), we can see that if an element is located on the right, it contributes to a lower time, as shown in Figure 15.

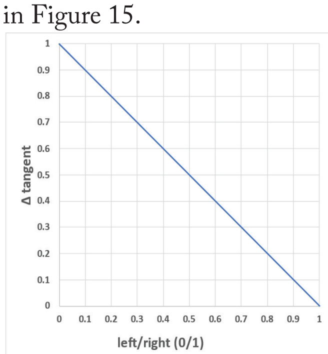

Figure 15: Left (0) or Right (1) – In most scenarios, the important element being located on the right side of a space, it will contribute to a lower time.

When looking at the slope to determine whether the important element is located within the center columns (1) or not (0), we can see that if an element is centered, it contributes to a lower time, as shown in Figure 16.

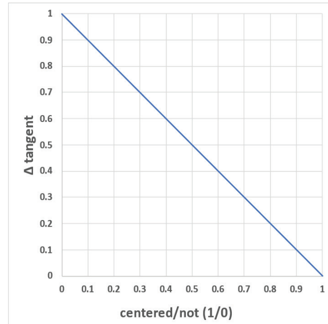

Figure 16: Centered (1) or Not (0) – In most scenarios, the important element being located in the central area of a space will contribute to a lower time.

When looking at the slope to determine whether the important element is organized in a standard - left-right, top-bottom - format (1), or not (0), we can see that if an element is not standard, it contributes to a lower time, as shown in Figure 17.

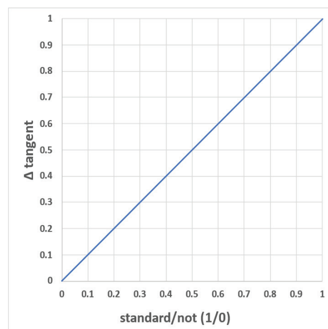

Figure 17: Standard (1) or Not (0) – In most scenarios, the important element being in the standard reading format will not contribute to a lower time.

When looking at the slope to determine whether the important element is grouped up with other elements (1) or not (0), we can see that if an element is not grouped up with other elements, it contributes to a lower time, as shown in Figure 18.

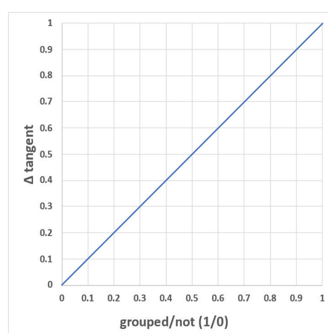

Figure 18: Grouped (1) or Not (0) – In most scenarios, the important element being located in a cluster of other elements in a space will not contribute to a lower time.

On the Colab program, a lambda of 500 results in a loss function of 0.005, while a lambda of 10,000 results in a loss function of 0.010, as shown in Figures 19 and 20.[7,8]

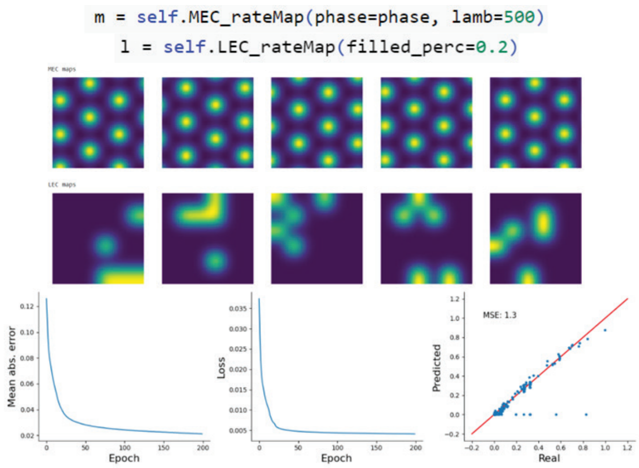

Figure 19: The neural network with a lambda value of 500; a shorter distance between the nodes of the firing field of grid cells results in a mean squared error (MSE) of 1.3.

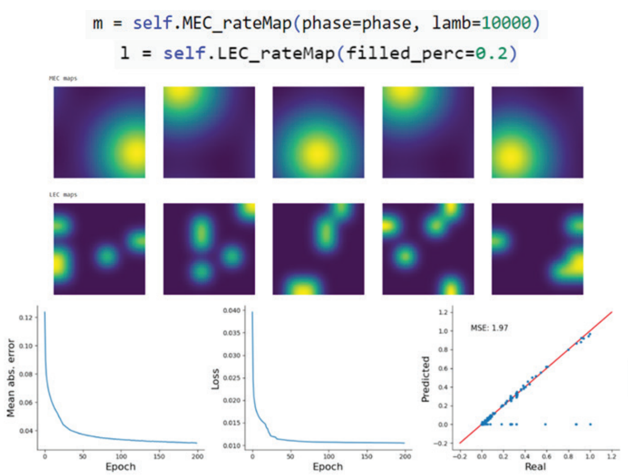

Figure 20: The neural network with a lambda value of 10,000; a farther distance between the nodes of the firing field of grid cells results in a mean squared error (MSE) of 1.97.

With the lambda at 500, a filled percentage of 80% results in a mean absolute error of 1.33, whereas a filled percentage of 20% results in a mean absolute error of 0.8, as shown in Figures 21 and 22.

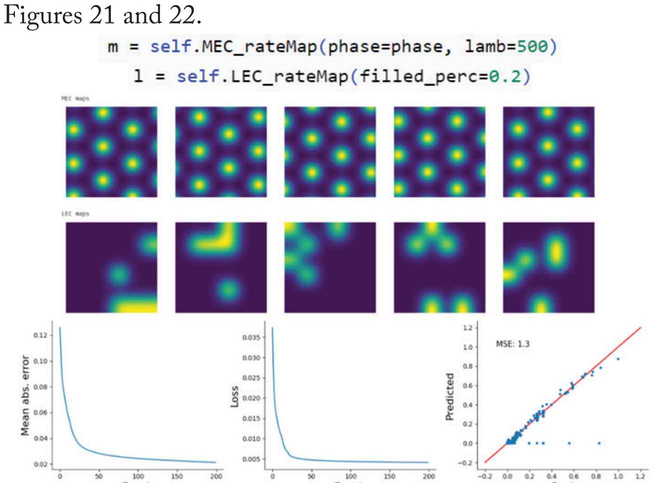

Figure 21: The neural network with a filled percentage value of 0.8 (80%); a higher coverage of the firing fields of grid cells results in a mean squared error (MSE) of 1.33.

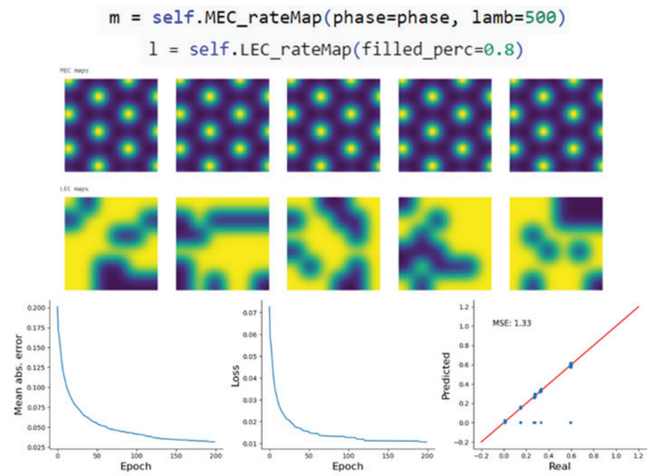

Figure 22: The neural network with a filled percentage value of 0.2 (20%); a smaller coverage of the firing fields of grid cells results in a mean squared error (MSE) of 0.83.

Discussion:

The factors grouped-or-not and centered-or-not can be explained with graph theory and centrality; because the variable centered-or-not can be linked to many other positions on the grid, it is more important than the other variables – it has a higher degree-centrality, which involves how many connections are linked to a vertex – resulting in less time. The variable grouped-or-not is important because clusters have a higher closeness-centrality. However, because the clusters have high closeness-centrality, it is harder to see individual vertices, resulting in longer times. Attention works with graph theory because high centralities tend to have more saliency; if an element is centered, it is more salient, attracting more attention. However, if an element is grouped, although it is more salient, it dilutes attention among multiple elements, as the brain needs to process each vertex/element individually.

Based on the positions of the text in each test trial, two common themes surfaced upon repeated experimentation. One was that the center of the environment gathered faster reaction times when the desired text was placed there. Second, slower reaction times came when the selected text was surrounded by other letters. These results can be adequately explained by the system of grid and place cells within the brain.

As for the results from the Colab, the two tests from adjusting the lambda (Figures 19 and 20) show that just like the fovea, grid, and place cells[3] have a bias towards the center of an environment. First, centered locations have overlapping firing fields for the grid and place cells, reinforcing the spatial representation compared to weaker responses for peripheral spots. Another reason is that center spots align with the hexagonal grid, obtaining a more robust response from grid cells. Regarding place cells, they rely on visual landmarks that detail an environment. Because the center of the environment is usually the first place an individual will view, place cells fire more robustly as this is the first visual landmark they anchor down.

For the two tests adjusting clustering (Figures 21 and 22), in terms of loss – the accuracy of the neural network's predictions – the program could pinpoint location more accurately with a lower filled percentage (obtaining a 0.005 value) while a

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higher filled percentage predicted location less accurately (obtaining a 0.01 value). These results can highlight many factors regarding difficulty locating text within a cluster. As in Figure 4, the density of letters makes it visually difficult to separate and identify individual objects, leading to less visual parsing.

Conclusion

In summary, we can use graph theory, game theory, and grid and place cell networks to develop the best combinations for positioning the elements of a poster, such that all the most important information is the first thing you see.

Put simply, the best combination when filling a plane with elements of various importance is to have the most important elements in their own distinct locations, away from other elements that may distract attention. It is often better to have the elements located in the center of the poster because not only does the center have the highest degree-centrality, but the grid and place cells also have a bias towards the fovea.

Avoid grouping important elements with less important elements, as it will increase the saliency of the whole cluster rather than what is more important because, as the simulation proves, it is much more difficult to see specific details when elements are grouped up.

Shapley values and collaborative game theory can be used within this topic to analyze further what makes important elements important and what other factors - such as color, contrast, and size - impact an element the most. Centrality and other concepts of graph theory - such as shortest path - can be used to organize the elements to create a more efficient information flow. Grid and place cells from cognitive neuroscience can be used to logically explain how and why a combination causes a viewer to react the way they do on a biological level.

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Author

Richard L. Wan is a 9th grader at Holicong Middle School. The paper was inspired by a recent science fair project, in which a similar set of rules was used to determine whether or not certain positions were better or worse for a visual (such as a poster).