# The Perception of Speed Altered by Visual Priming:

## Application: Design Pattern and Color

by

Brooke Baldwin

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved April 2021 by the
Graduate Supervisory Committee:

Aurel Coza, Co-Chair
Vaughn Becker, Co-Chair
Robert Gray

ARIZONA STATE UNIVERSITY

May 2021

## ABSTRACT

In an ever-faster world, products that are designed for enhancing the speed of a certain task can and are being designed in rapid iterations by means of adding or modifying features that impact the energetics, kinematics and kinetics of a given product. Given the ubiquity of said changes and the need to market these products in a very crowded marketplace, it is imperative for the products to communicate the ‘speed’ of the additional features. Thus, it has been hypothesized that adding a few simple changes to the visual representation of a product or the context in which it is being presented could enhance the perception of the product dynamics at a cognitive or emotional level. The present work is aimed at determining the impact of visual elements such as shapes, colors, and textures on the perception of speed. Three hundred and twenty subjects participated in a discrimination task and a reaction task to measure the impact of various patterns, textures, and colors on the perception of speed. Throughout both tasks, the subjects were exposed to a number of various visual patterns or colors presented as a static background or recognizable object for a set amount of time. Based on the subjects’ performance we have identified and quantified the impact of specific visual design patterns and colors on the perception of speed. Primary results indicate promising evidence that certain fundamental visual elements of shape, color, and texture when presented as a static background or object design could induce subtle changes in visual perception that can alter the overall movement dynamics perception.

TABLE OF CONTENTS

APPENDIX Page

LIST OF TABLES

Table Page

LIST OF FIGURES

**The perception of speed altered by visual priming: application: design pattern and color**

Nowadays, consumption of goods and services is a behavior that defines individual and social life of human beings (Ratneshwar & Mick, 2005). Consumers purchase products on a daily basis whether it is out of a need or a want and past research has shown that these purchases are reliant on the consumer's current motivations, desires, and goals (Griskevicius & Kenrick, 2013; Dunning, 2007). Each and every product is perceived uniquely by the consumer and based on their perception determines how, when and why consumers decide to purchase it (Agyekum et. al, 2015). Every item or product that is in production has many withholding elements. Examples of these elements can be seen as price, availability, product specifications, marketing, product brand and reputation. These elements have the ability to influence the overall perception and decision of consumers purchasing the product. These elements can vary widely from product to product but the product itself has very basic characteristics. The generic aspect of the product presents the creator of said product with the opportunity to make each item distinct from other items that are similar on the market. One instance of making a generic product more distinct would be by adding value through extra features such as performance enhancements.

When looking specifically at products that are being designed with the intention of enhancing its performance such as sports cars, athletic apparel, aircrafts, etc., designers and engineers rely on time proven mechanical features to increase performance. Each iteration of a given product either adds a new feature or modifies one or more existing features in order to try and impact (mechanically) the energetics, kinematics and kinetics, thus, achieving a higher movement efficiency and/or improving any of the performance related variables of interest (Frederick, 1984; Frederick, 1986. Frederick (1984) researched the ergonomic design features of running shoes and their effect of performance on the runner. The general findings concluded that traction, cushioning, and weight are important features needed to enhance the  performance of the athlete. A later study conducted by Frederick (1986) found that shoe design and adjustments made can be a powerful tool used to manipulate human kinematics and kinetics in general. That being said, there are products that are designed with many features that actually improve the speed but the new features or mechanical improvements are hidden. For instance, a ‘super engine’ on a sports car is concealed under the nontransparent hood where no one can see it. In order to communicate to consumers the specific product attributes (eg. power), one has to devise a distinct ways to market and/or advertise it. While these perception variables have been at the forefront of product selection for decades, it was not until recently that manufacturers started taking advantage of the opportunity to present them. The car company Ferrari took advantage of this opportunity when they implemented a transparent engine cover that offered a sneak peak of their distinctive engine of their flagship F-50 model. By being able to see what this special engine looks like, and how it is visually different from the typical engine, it gives a more dramatic appeal and adds more emotional weight to it.

However, in certain situations, a significant mechanical intervention is not possible because the theoretical and practical limits of a given mechanical feature have been reached. Additionally, the technological, economic, market preferences or design constraints may not allow for changes that would have a significant, direct, mechanical impact. When these limitations of mechanical impossibility or a hidden improvement are shown, it can still be possible to create products that can lead to an increase in performance by means of inducing subtle changes in the visual perception of a two-dimensional environment that can alter the overall movement dynamics at a cognitive and emotional level (Skylott et al., 2013; Valencia-Romero, 2016). Valencia-Romero and colleagues (2016) looked at how the Gestalt principles can generate a variety of two-dimensional designs and determine how design preferences change as a function of design attributes. Results showed that visual elements of Gestalt principles can produce esthetically pleasing designs specifically looking at symmetry and continuity. Based on these results, a product's form can be used to develop discrete choices to elicit selective consumer preferences. Alternatively, Skylott et. al (2013) tested the hypothesis that when consumers make decisions, they take into account both the function of the product and the form of the product. Researchers found that the regions of the brain corresponding to emotional responses are activated during the decision making of the product choice (Skylott et. al, 2013). Understanding consumer preferences through cognitive processes may provide useful insight to guide designers during the product and/or experience creation process.

Communicating the improvements or features of a given product is key to successfully advertise the product as the best option for an interested consumer. By taking a deeper look into the visual design elements of the product itself or the background it is placed on, it is possible to induce changes in the movement patterns and perception of speed (Stone & Thompson, 1992; Manser & Hancock, 2007). Stone and Thompson (1992) looked at the effect of different contrasts on the perceived speed of gratings. Specifically examining what spatial frequency and orientation of the gratings through different contrasts can do to speed perception (Stone & Thompson, 1992). Results indicated that the ability to distinguish differences in speed were not affected by the contrasts alone, but the contrasts combined with orientation of the gratings did induce differences in speed perception (Stone & Thompson, 1992). Relatedly, Manser & Hancock (2007) conducted research to see if the type of visual pattern and presence of texture applied to tunnel walls would affect driving performance. Participants in the study were exposed to vertical visual patterns that varied widths. Results indicated that the drivers gradually decreased speed when exposed to the decreasing width visual pattern and increased speed with the increasing width visual pattern (Manser & Hancock, 2007). It has been shown throughout research that the presence of specific visual textures have the ability to alter the perception of speed but a study has not yet been done comparing various textures and patterns all together.

For online shopping experiences, communicating the benefits of a product becomes challenging because the physical item is not present. Anecdotally, humans rely on visual and perceptual cues to navigate their everyday environment. Due to the large gap between having a product physically present versus visually seeing a two-dimensional image or advertisement online, companies selling products online need to create some type of cognitive affordance through visual and perceptual attributes to get the point across. If a company's goal is to make a product seem quick or fast online, special visual design accommodations need to be made so that the targeted consumers perceive the product as 'faster'. By creating a cognitive affordance that helps aid the perception of speed, the visual perception or illusion of the product and the environment it is placed in, can act as a filter or amplifier for various variables related to the consumers perception.

The most prevalent method used to communicate the improvements or features of the chosen product is leveraging a company's design language. Design language consists of fonts, icons, colors and shapes used to visually communicate a company's brand identity and therefore builds a visual idea or opinion on the perception of their goods or services. Design language is widely used in user experience or user interface design to improve dynamic interactions and deliver the type of experiences the consumer is looking for (Cairns et. al, 2019). Perceptual and visual variables such as patterns, textures and color, which are integral to design language, can improve (or impair) the visual perception of speed performance. An illustration of such visual and perceptual design variables within two dimensional environments would be the design theory of Gestalt. Gestalt theory is based on the idea that the human brain will attempt to simplify and organize complex images or designs that consist of many elements, by arranging the parts into an organized system that creates a whole, rather than just a series of separate elements (Chang et. al, 2002; Graham, 2008). Graham (2008) demonstrated how Gestalt theory is used in interactive media design such as websites and the importance of the perception variables for the interactive designer and user to be able to understand the structure and organization of the media's interface. Chang et. al (2002) tested a learning application using eleven Gestalt design principles and results indicated that the new design principles improved the applications appearance and the value for learning. The human mind is built to see these structures and patterns organizationally in order for us to better understand our surrounding environment. Thus, patterns can easily be used to manipulate environmental perception by using the basic principles of proximity, continuity, closure, symmetry, parallelism, and similarity (Lugo et al., 2015; Valencia-Romero, 2016). Furthermore, Lugo et. al (2015) details an approach on how designers can combine design shapes and the gestalt principles in the context of two dimensional product environments to generate new design practices in a variety of fields. In the present study we used the design fundamentals of dots, lines and planes in parallel with Gestalt principles to create our 11 black and white patterns.

Aside from textures and patterns, visual design elements of colors can also be used to alter our perception. Specifically looking into the way colors have been shown to have the ability to alter our speed perception. Past research has shown mixed findings on perceived speed of colors. Some research found that low contrast colors appear to move more slowly than high contrast colors (Dougherty et. al, 1999). Dougherty et. al (1999) came to this conclusion by measuring the perceived speed of colored stimuli through a speed matching task. This could be due to the neural mechanisms that limit visibility and the mechanisms governing speed perception are different (Dougherty et. al, 1999). Others such as Stone & Thompson (1992) examined what spatial frequency and orientation of the gratings through different contrasts can do to speed perception and found that the ability to distinguish differences in speed were not affected by the contrasts alone, but the contrasts combined with orientation of the gratings did induce differences in speed perception (Stone & Thompson, 1992). Additionally, the specific color red has been shown to have the ability to alter emotions physiologically and psychologically (Mentzel el. Al, 2017; Shibasaki & Masataka, 2014) Research by Mentzel and colleagues (2017) compared the color red to blue and gray and participants showed a faster reaction time and less errors when organizing dominance words shown in red. Their study suggests that the ability to alter emotions could be due to a link between the color red and perceived dominance. Shibasaki & Masataka (2014) investigated the effect of time perception on the color red versus blue and concluded that color red can exert certain special psychological effects on human behavior. However, researchers have found no color effects for red in a sports performance environment (Garcia-Rubio, 2011). Besides the color red, other colors can create aesthetic and psychological responses that can influence our physical and emotional sensations (Mikellides, 2012). The study conducted by Mikellides (2012) looked at whether differences in hues affect our perception and feeling of warmth at the cognitive as well as the physiological level. Results indicated that hues such as red, orange and yellow are seen as warmth as well as exciting and stimulating, whereas hues such as blue and green are seen as cool, calming and relaxing.

Given the confusion surrounding the topic of color perception and the lack of past research looking at colors systematically, for this study we have focused on the impact of 12 popular colors, on the perception of speed.

Within two-dimensional environments, such as most traditional online marketing advertisements, video games, or online webpages; design elements are implemented to create something that promotes the visuals seen on the display. Depending on the goal of the visual design there are strategies that can be implemented to create and enhance the overall perception. Regardless of whether one is attempting to manipulate the perception of an object's speed visually or through the design of a new product, the ability to quantify and understand the impact of visual elements and stimuli is a critical step in the product design process. Visual appearance is the very first impression made on a user or consumer. Research has shown that a product can be judged within 50 milliseconds of seeing it by the user or consumer (Lindgaard et. al, 2006). Within those 50 milliseconds the decision could result in the acquisition or termination of the given product or brand. Communicating the given product through exposure to various visual designs connects the user or consumer psychologically through physical and emotional awareness. That being said, designing for the users' needs and wants is a lot easier said than done. There are many types of visual stimuli that can create a psychological response, or even a desired psychological response, for the consumer or user to use or purchase the targeted product. By taking a closer look into a few fundamental visual elements of shape, color and texture and seeing the influence the designs can have on the human eye and brain are an important step forward in present day design.

In this study, we created a number of methodologies and quantification tools to measure the impact of novel, perception-oriented features on speed perception. Specifically, trying to find a systematic understanding and mapping of the impact of three fundamental visual elements (shape, color and texture) on the perception of speed. It is known that color and shape can change the perception of dynamics of a background or object so in this study we attempted to systematically change the perception by finite patterns and colors that are broadly used in the design world. The eleven black and white patterns used in this research were chosen based on the basic principles of Gestalt such as proximity, continuity, closure, symmetry, parallelism, and similarity combined with design shapes such as dots, lines, and planes (Lugo et al., 2015; Valencia-Romero, 2016). The twelve colors were chosen based on the color wheel of the classic warm and cool colors (Bailey et. al, 2006). By using these eleven patterns and twelve colors we are attempting to cover a broad range of design elements that have not been researched together before.

A byproduct of looking into the impact of these certain shapes, colors, and textures, is a design elements catalogue that can be created that ranks these various designs based on their propensity to change the visual perception principles of speed and performance. Being able to understand how certain designs can influence certain visual cues will be helpful in the marketing of various products. The following experiment was an exploratory study looking at all eleven patterns and twelve colors designed to test the following hypotheses:

(i) The accuracy of the execution of a dynamic reaction task will be altered by the exposure to various design backgrounds and the exposure to various color backgrounds.

(ii) The perceived speed of a moving simulated object will be altered as a function of the design pattern of said object and the color of said object.

## Methods

### Procedure

The study was conducted through the Mechanical Turk survey platform. Once subjects accepted to perform the HIT on the Mechanical Turk platform, they were redirected to the experiment in Qualtrics. Within the survey in Qualtrics, subjects gave informed consent, received instructions to complete the two tasks in the survey and learned other details about the study such as estimated time, length, reward, and the privacy of their personal information. The study consisted of two tasks, one reaction and one discrimination, and the first condition included 11 black and white patterns made from shapes and textures. The second condition consisted of the same two tasks, one reaction and one discrimination, that included 12 solid colors. The colors were chosen based on the color wheel of the classic warm and cool colors (see appendix A). Since we are looking at the perception of speed, we are placing the color on a recognizable product, a shoe backdrop.

Table 1

*Study Procedure*

| Condition 1 (Patterns) | Condition 2 (Colors) |
|---|---|
| 1. Consent Form | 1. Consent Form |
| 2. Task 1 Instructions Given | 2. Task 1 Instructions Given |
| 3. Task 1: Reaction Task* | 3. Task 1: Reaction Task* |
| 4. Task 2 Instructions Given | 4. Task 2 Instructions Given |
| 5. Task 2: Discrimination Task* | 5. Task 2: Discrimination Task* |

*all conditions randomized

**Design**

The present study implemented a 2x2 within subjects design. Independent variables included the 11 patterns in condition one and 12 colors in condition two. There are 11 repeated measures across the different patterns and 12 repeated measures across different colors, all measured with the two tasks.

Table 2

*Study Design*

| Study Design | Condition 1 | Condition 2 |
|---|---|---|
| Task 1: Reaction Task | Patterns (11 repeated tests) | Colors (12 repeated tests) |
| Task 2: Discrimination Task | Patterns (11 repeated tests) | Colors (12 repeated tests) |

**Task 1: Reaction Task**

The first stimuli was a reaction task created through an open source software based on a study done by Dijksterhuis et. al (2013). Dijksterhuis et. al (2013) conducted a study on the visuomotor workload in a driving simulator by changing the speed and measuring the standard deviation of the cars lateral position. The speed of the simulated vehicle had a significant effect on the lateral positioning on the driving lane (Dijksterhuis et. al, 2013). Based on the results from this study we created a simulated reaction task that consisted of an animated vehicle on a winding road with the background of the software randomly switching between the 11 patterns or 12 colors, depending on the condition, every 15 seconds (see appendix D and E). The objective of the task was for the subject to keep the animated vehicle in the middle of the dotted line throughout the entire session using the arrow keys on their keyboard. The idea was for the perception of speed to be influenced by the design of the background, either shapes and texture or the color, and the reaction time of the task will be affected by the given background. Based on the deviation from the center line we can assume that the background colors or patterns will be affected by the perceived speed.

**Task 2: Discrimination task**

The second stimuli was a product targeted approach through a discrimination task created with custom software for silhouettes of a recognizable product that controlled the dynamics and speed of each. The recognizable product used in this study was a shoe. The silhouettes consisted of the same 11 patterns, shapes and 12 colors as the prior reaction task and the speed profile of the shoe conditions varied (1x, 2x, 3x) (see appendix B and C). Subjects watched two silhouettes (the control paired with one of the 11 randomized patterns or 12 randomized colors) cross the screen at a randomized speed. Once each pair of silhouettes had crossed the screen, the subject was asked which one they perceived as faster. The control shoe and visual shoe moved at the same speed.

**Participants**

One hundred and eighty-five subjects participated in task one of the study and one hundred and thirty-one subjects participated in the second task. The subjects were recruited remotely through the Mechanical Turk platform with reported ages over 18 years. The location of the subjects was spread globally throughout six countries. The survey was restricted to subjects with a rating approval from other human intelligence tasks (HITs) of 95% or higher. The subjects who accepted to participate in the study were redirected to the survey through a link in the Mechanical Turk platform. The average completion time was 14 minutes.

All participants were given informed consent and the experiment obtained ethics approval by the University Institutional Review Board (IRB) for STUDY00013035. The compensation reward was $2 for their participation.

## Data Analysis

For the first task, the difference between the position of the simulated vehicle & the center of the animated road was recorded every 0.5 seconds and saved in an array called Delta. There were 30 data points recorded for each individual pattern or color. The average standard deviation for each subject was recorded for each pattern or color. Based on the various screen resolutions used by the subjects, we normalized the data before analyzing the data with a paired t-test.

For the second task, researchers counted the number of times the speed had been perceived as faster or slower and used that data to rank the designs and colors of the perceived speed. Due to the categorical variables, shoe 1 or shoe 2, researchers used Fisher's exact test of independence to see whether the proportions of one variable were different depending on the value of the other variable.

# Results

## Condition 1 (Patterns): Reaction Task

*Figure 1* shows the mean values in the first condition of the pattern visual designs. Visually there are some differences between the patterns. The triangles pattern showed the lowest mean center line deviation compared to the diamond pattern that has the highest mean center line deviation.

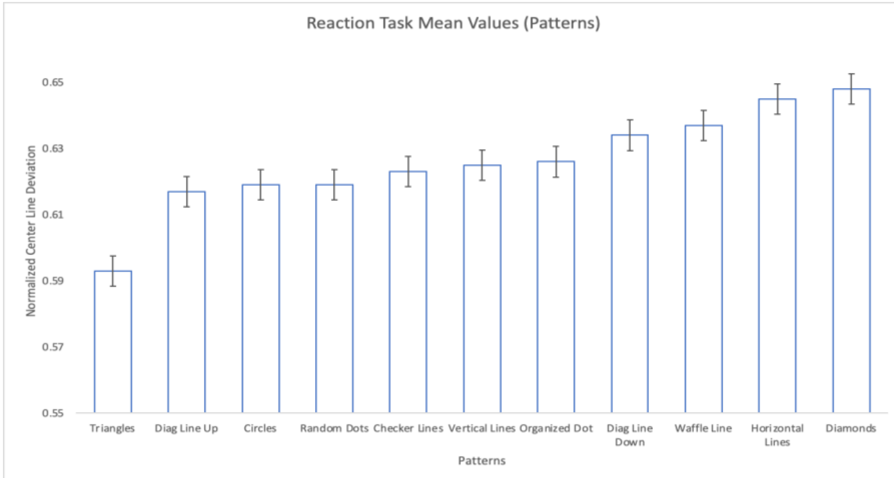



*Figure 1.* Mean values of the reaction task for the 11 patterns. Error bars are one standard deviation.

*Table 3* shows the significant results of the paired t test that was used to compare the mean of two patterns. Two pairs have shown statistically different means indicating a slight effect of background patterns on the perception of speed. The triangles pattern (mean = .59; SD = .24) and horizontal lines (mean = .65; SD = .23), showed a significant difference of $p < .02$. Triangles (mean = .59; SD = .24) and diamonds (mean = .65; SD = .21) showed a significant difference of $p < .01$. See table below.

Statistical t-test results for the grouped patterns (dots, lines and planes) indicated that there are no significant differences between the dots, lines or planes in the reaction task. However, a detailed analysis (see Table 3) has shown that individual patterns induced speed perception changes can be statistically different from each other. Given the exploratory nature of this study, the values in Table 3 were not corrected for Type 1 familywise errors as none of the individual comparisons are used to support an overarching hypothesis.

Table 3

*Reaction Task P-Values for Patterns*

| p-values t-test center line deviation | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Patterns** | **Organized Dot** | **Horizontal Line** | **Vertical Lines** | **Checker Line** | **Waffle Line** | **DiagLineDown** | **DiagLineUp** | **Circles** | **Triangles** | **Diamonds** | **Random Dot** |
| **Organized Dot** | 1.00 | 0.38 | 0.98 | 0.90 | 0.63 | 0.69 | 0.72 | 0.74 | 0.15 | 0.30 | 0.78 |
| **Horizontal Line** | | 1.00 | 0.36 | 0.33 | 0.73 | 0.62 | 0.22 | 0.20 | 0.02 | 0.89 | 0.25 |
| **Vertical Lines** | | | 1.00 | 0.92 | 0.60 | 0.66 | 0.73 | 0.75 | 0.15 | 0.27 | 0.79 |
| **Checker Line** | | | | 1.00 | 0.55 | 0.60 | 0.82 | 0.85 | 0.21 | 0.25 | 0.88 |
| **Waffle Line** | | | | | 1.00 | 0.91 | 0.41 | 0.41 | 0.07 | 0.63 | 0.45 |
| **DiagLineDown** | | | | | | 1.00 | 0.44 | 0.44 | 0.06 | 0.52 | 0.49 |
| **DiagLineUp** | | | | | | | 1.00 | 0.96 | 0.29 | 0.16 | 0.93 |
| **Circles** | | | | | | | | 1.00 | 0.24 | 0.14 | 0.97 |
| **Triangles** | | | | | | | | | 1.00 | 0.01 | 0.25 |
| **Diamonds** | | | | | | | | | | 1.00 | 0.18 |
| **Random Dot** | | | | | | | | | | | 1.00 |

**Condition 1 (Patterns): Discrimination task**

*Figure 2* shows the frequency of which shoe was perceived as faster within the discrimination task of condition one. Based on the figure, triangle patterns are perceived the slowest whereas horizontal line and vertical line patterns are perceived the fastest. Overall, patterns that are created with lines and dots show higher perceived speed compared to patterns that consist of planes.

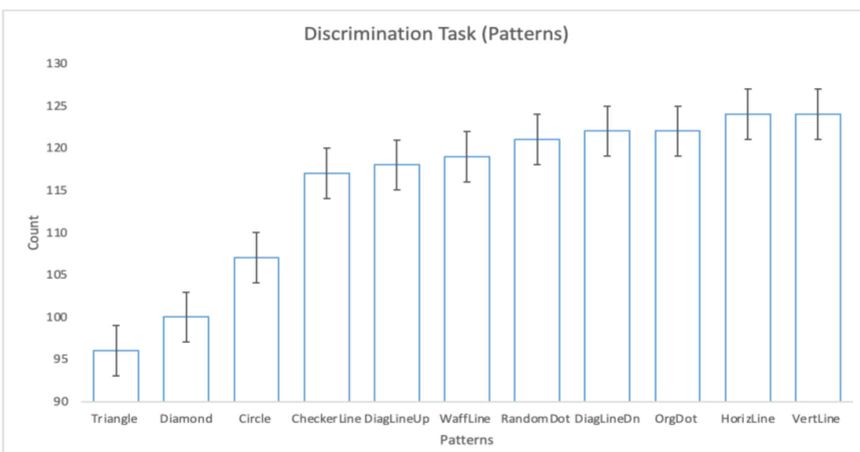



*Figure 2.* Descending to ascending ranking of the faster perceived pattern. Error bars are one standard deviation.

*Figure 3* shows the number of times the moving object with a certain design pattern was perceived as faster/slower in comparison with the control pattern.

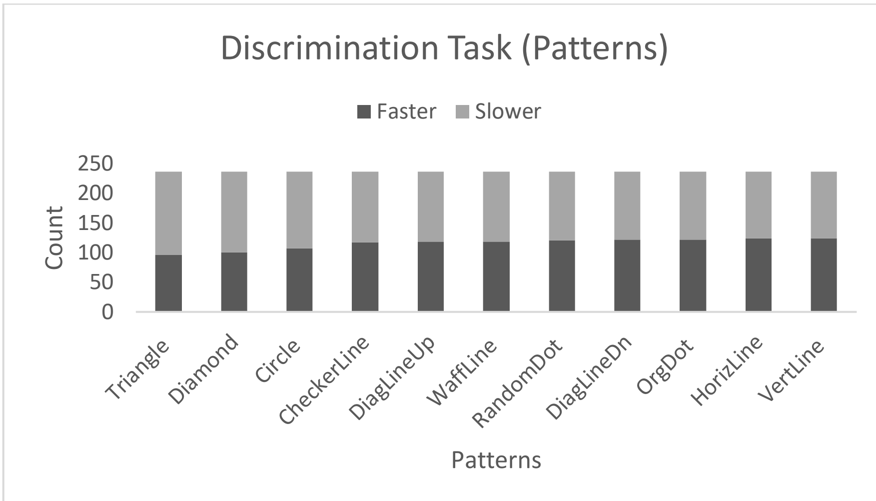



*Figure 3.* Count for reaction task for the 11 patterns comparing the perception of faster or slower to the control pattern.

*Table 4* shows the results from Fisher's exact test of independence to see whether the proportions of one pattern were different depending on the value of the other pattern. Primary outcome results indicated eleven pairs to have significantly different results. The diagonal lines down 51.47% (n=122/237) were significantly different compared to the diamonds 42.19% (n=100/237) = $p < .05$ and 40.5% (n=96/237) within the triangles = $p < .02$. Diagonal lines up 40.79% (n=118/237) and triangles 40.5% (n=96/237) were significantly different resulting in $p < .05$. Diamonds 42.19% (n=100/237) were significantly different compared with horizontal lines 52.32% (n=124/237) = $p < .03$, organized dots 51.48% (n=122/237) = $p < .05$, and vertical lines (n=124/237) = $p < .03$. Horizontal lines 52.32% (n=124/237) and triangles 40.5% (n=96/237) were significantly different resulting in $p < .01$. Organized dots 51.48%

(n=122/237) and triangles 40.5% (n=96/237) were significantly different showing p < .02. The comparison of random dots 51.05% (n=121/237) and triangles 40.5% (n=96/237) were significantly different p < .03. Lastly, triangles 40.5% (n=96/237) were significantly different compared to vertical lines 52.32% (n=124/237) = p < .01 and waffles lines 50.21% (n=119/237) = p < .04. See table below.

Statistical analysis results of Fisher's exact test for the grouped patterns of dots, lines and planes indicated a significant difference in dots versus planes with a p value < .0036 and lines versus planes with a p value < .005. A detailed analysis (see Table 4) has shown however that individual patterns induced speed perception changes can be statistically different from each other. Given the exploratory nature of this study, the values in Table 4 were not corrected for Type 1 familywise errors as none of the individual comparisons are used to support an overarching hypothesis.

Speed interaction between patterns in the discrimination task were also analyzed. Results from Fisher's exact test indicated no speed interaction for the patterns within the task. Based on this, we can conclude that speed does not have an impact on the perception of patterns.

Table 4

*Fisher's Significant Test for design patterns in the reaction task.*

| | Fisher's Test Significance Values for 11 Design Patterns | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Patterns** | **CheckerLine** | **Circle** | **DiagLineDn** | **DiagLineUp** | **Diamond** | **HorizontalLine** | **OrganizedDot** | **RandomDot** | **Triangle** | **VerticleLine** | **WaffleLine** |
| **CheckerLine** | 1.00 | 0.41 | 0.71 | 1.00 | 0.14 | 0.58 | 0.71 | 0.78 | 0.06 | 0.58 | 0.93 |
| **Circle** | | 1.00 | 0.20 | 0.36 | 0.58 | 0.14 | 0.20 | 0.23 | 0.35 | 0.14 | 0.31 |
| **DiagLineDn** | | | 1.00 | 0.78 | 0.05 | 0.93 | 1.00 | 1.00 | 0.02 | 0.93 | 0.85 |
| **DiagLineUp** | | | | 1.00 | 0.12 | 0.65 | 0.78 | 0.85 | 0.05 | 0.65 | 1.00 |
| **Diamond** | | | | | 1.00 | 0.03 | 0.05 | 0.07 | 0.78 | 0.03 | 0.10 |
| **HorizontalLine** | | | | | | 1.00 | 0.93 | 0.85 | 0.01 | 1.00 | 0.71 |
| **OrganizedDot** | | | | | | | 1.00 | 1.00 | 0.02 | 0.93 | 0.85 |
| **RandomDot** | | | | | | | | 1.00 | 0.03 | 0.85 | 0.93 |
| **Triangle** | | | | | | | | | 1.00 | 0.01 | 0.04 |
| **VerticleLine** | | | | | | | | | | 1.00 | 0.71 |
| **WaffleLine** | | | | | | | | | | | 1.00 |

**Condition 2 (Colors): Reaction Task**

*Figure 4* shows the mean values in the first condition of the color visual designs. Visually there are some differences between the colors. The yellow orange color showed the lowest mean center-line deviation compared to the color blue violet that has the highest mean center-line deviation.

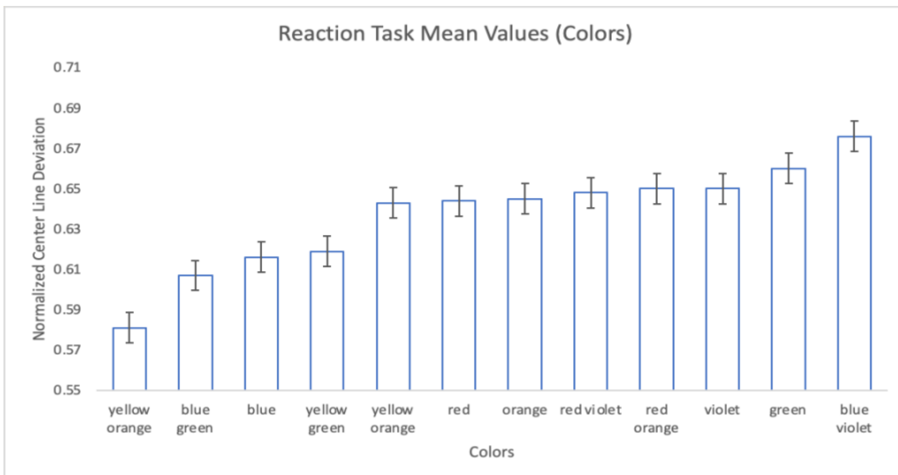



*Figure 4.* Mean values of the reaction task for the 12 colors. Error bars are one standard deviation.

*Table 5* shows the mean values in the first condition of the color visual designs. A paired t test was used to compare the mean of two colors. In our comparison of yellow orange (mean = .58; SD = .22), green (mean = .66; SD = .21) showed a significant difference of $p < .03$ along with blue violet (mean = .67, SD = .19) = $p < .05$ and violet (mean = .65; SD = .19) = $p < .05$. Blue green (mean = .60; SD = .20) showed a significant difference of $p < .04$ with blue violet (mean = .67; SD = .19). See table below.

Statistical t-test results for the grouped colors indicated that there are no significant differences between warm and cool colors. Additionally, researchers analyzed using the t-test to see if there was a difference between the primary colors of light: red, green, and blue (RGB). Results from the t-test indicated that there is no significant differences between the colors red, green, and blue. However, a detailed analysis (see Table 5) has shown that individual colors induced speed perception changes can be statistically different from each other.

Table 5

*Reaction Task P-Values for Colors*

| p-values t-test center line deviation | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Colors | red | red-orange | orange | yellow-orange | yellow | yellow-green | green | blue-green | blue | blue-violet | violet | red-violet |
| red | 1.00 | 0.86 | 0.97 | 0.07 | 0.96 | 0.50 | 0.64 | 0.27 | 0.42 | 0.33 | 0.86 | 0.90 |
| red-orange | | 1.00 | 0.90 | 0.06 | 0.85 | 0.41 | 0.76 | 0.21 | 0.34 | 0.43 | 1.00 | 0.97 |
| orange | | | 1.00 | 0.09 | 0.94 | 0.50 | 0.69 | 0.29 | 0.43 | 0.39 | 0.90 | 0.94 |
| yellow-orange | | | | 1.00 | 0.12 | 0.33 | 0.03 | 0.47 | 0.36 | 0.01 | 0.05 | 0.07 |
| yellow | | | | | 1.00 | 0.57 | 0.65 | 0.35 | 0.50 | 0.37 | 0.85 | 0.88 |
| yellow-green | | | | | | 1.00 | 0.28 | 0.75 | 0.93 | 0.13 | 0.41 | 0.45 |
| green | | | | | | | 1.00 | 0.13 | 0.23 | 0.65 | 0.76 | 0.74 |
| blue-green | | | | | | | | 1.00 | 0.81 | 0.04 | 0.20 | 0.24 |
| blue | | | | | | | | | 1.00 | 0.09 | 0.33 | 0.37 |
| blue-violet | | | | | | | | | | 1.00 | 0.43 | 0.42 |
| violet | | | | | | | | | | | 1.00 | 0.97 |
| red-violet | | | | | | | | | | | | 1.00 |

**Condition 2 (Colors): Discrimination task**

*Figure 4* shows the frequency of which shoe was perceived as faster within the discrimination task of condition two. Condition two consisted of the design principle of colors. Based on the figure, the yellow orange color is perceived the slowest compared to the blue violet color which is perceived as the fastest.

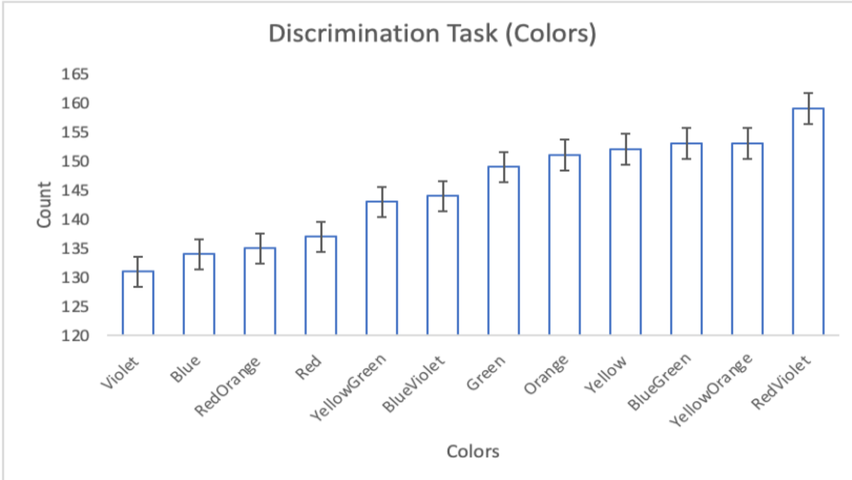



*Figure 4.* The color violet is perceived the slowest compared to the control color whereas the color red violet is perceived the fastest. Error bars are one standard deviation.

*Figure 5* shows the number of times the moving object with a certain design color was perceived as faster/slower in comparison with the control color.

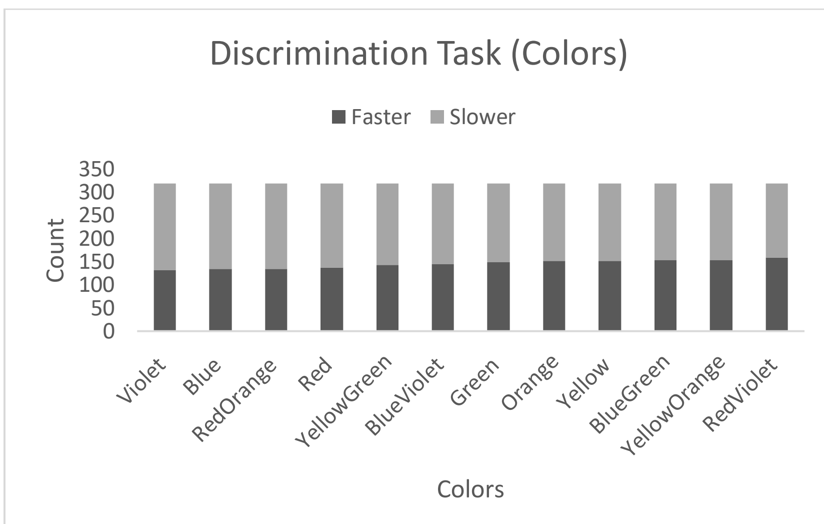



*Figure 5.* Count for discrimination task for the 12 colors comparing the perception of faster or slower to the control color.

*Table 6* shows the results from Fisher's exact test of independence to see whether the proportions of one color were different depending on the value of the other color. Primary outcome results indicated a significant difference in the perceived speed of the violet color 41.19% (n=131/318) compared to 50% (n=159/318) within the red violet ($p < .03$). See table below.

Statistical analysis results of Fisher's exact test were done for the grouped colors. Primary outcome results indicated no significant difference between warm colors versus cool colors ($p < 1.0$) and no significant difference between the primary colors. The assumption that grouping colors together would show a differential effect is unsubstantiated by the results. A detailed analysis (see Table 7) has shown however that individual patterns induced speed perception changes can be statistically different from each other.

The speed interaction for the colors within the discrimination were examined. Results from Fisher's exact test indicated no speed interaction between the colors. Based on this, we can conclude that speed does not have an impact on the perception of colors.

Table 6

*Significant differences between the design colors in the reaction task.*

| | Fisher's Test of Significance Values (Colors) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Colors | Violet | Blue | RedOrange | Red | YellowGreen | BlueViolet | Green | Orange | Yellow | BlueGreen | YellowOrange | RedViolet |
| Violet | 1.00 | 0.87 | 0.81 | 0.69 | 0.38 | 0.34 | 0.17 | 0.13 | 0.11 | 0.09 | 0.09 | 0.03 |
| Blue | | 1.00 | 1.00 | 0.87 | 0.52 | 0.47 | 0.26 | 0.20 | 0.18 | 0.15 | 0.15 | 0.06 |
| RedOrange | | | 1.00 | 0.94 | 0.58 | 0.52 | 0.30 | 0.23 | 0.20 | 0.18 | 0.18 | 0.07 |
| Red | | | | 1.00 | 0.69 | 0.63 | 0.38 | 0.30 | 0.26 | 0.23 | 0.23 | 0.09 |
| YellowGreen | | | | | 1.00 | 1.00 | 0.69 | 0.58 | 0.52 | 0.47 | 0.47 | 0.23 |
| BlueViolet | | | | | | 1.00 | 0.75 | 0.63 | 0.58 | 0.52 | 0.52 | 0.27 |
| Green | | | | | | | 1.00 | 0.94 | 0.87 | 0.81 | 0.81 | 0.48 |
| Orange | | | | | | | | 1.00 | 1.00 | 0.94 | 0.94 | 0.58 |
| Yellow | | | | | | | | | 1.00 | 1.00 | 1.00 | 0.63 |
| BlueGreen | | | | | | | | | | 1.00 | 1.00 | 0.69 |
| YellowOrange | | | | | | | | | | | 1.00 | 0.69 |
| RedViolet | | | | | | | | | | | | 1.00 |

## Task Comparison

*Table 7* shows the comparison across the discrimination task and the reaction task to see if there are any similar relationships between the two conditions of patterns and colors. Based on the comparison between task one and task two for the color designs, there is a clear overlap of violet hues and green hues as well as differences of yellows. For the comparison on design patterns, lines seem to be perceived the fastest across both tasks.

Table 7

*Task Comparison Between Conditions*

| | **Task Comparison** | |
|---|---|---|
| **Task** | **Colors** | **Patterns** |
| **Reaction Task** | Blue Violet<br>Green | Horizontal Lines<br>Diamonds |
| **Discrimination Task** | Red Violet<br>Yellow Orange<br>Blue Green<br>Yellow | Horizontal Lines<br>Vertical Lines<br>Diagonal Lines Down<br>Diagonal Lines Up |

## Discussion

The goal of this study was to measure the impact of systematic changes of color and texture on speed perception. Specifically, this study is a first attempt to systematically quantify and 'map' the impact of three fundamental visual elements (shape, color and texture) on the perception of speed when presented through a static background or the design of a recognizable object per-se.

The primary findings of this study showed that various designs using shapes, textures and colors can in fact, influence the perception of speed in a two-dimensional environment. Four pairs of patterns had statistically different means indicating an effect of background patterns on the perception of speed. This was demonstrated by means of using an immersive environment as a proxy for the perception of a moving object in front of a background of controllable patterns. Similarly, four pairs of colors had statistically different means indicating a slight effect of background colors on the perception of speed throughout the reaction task. We can assume speed perception was altered in the reaction task based on the assumptions made by Dijksterhuis et. al (2013) in their study measuring the standard deviation of the simulated vehicles lateral positioning. Based on these results, one can create recommendations on how various products can be advertised with stylistic backgrounds to trigger a specific perception of speed (high or low) for a given audience. Additionally, results to measure whether the proportions of one pattern were different depending on the value of the other pattern indicated eleven pairs to have significant results shown in the product targeted approach for the discrimination task. Lastly, one pair of colors were significantly different in the product-targeted approach for the discrimination task indicating that for this particular setup, color may impact the perception of speed but to a lesser degree than the patterns. Based on these results, not only does the background design influence the consumers perception, but also the design of the object itself can contribute to this effect.

It is notable that the grouping of colors or patterns together had no specific results that prevailed. For colors grouped together as cool versus warm or as primary colors in the discrimination task and reaction task, there were no significant differences. As a result, differences are only seen at an individual level for specific colors within the two tasks. Conversely, patterns grouped together into the three fundamental elements of dots, lines and planes did show significant differences in the discrimination task. Results indicated that dots versus planes are significantly different along with planes versus lines.

Given these results, one can rank the various designs and colors based on their propensity to change the visual perception principles of speed. The findings of this study can also be utilized to guide designs and advertisements in application areas where it is crucial where users perceive products in terms of speed. By generalizing these results, they can be implemented into the designing, marketing and advertising for companies and manufacturers around the world. Additionally, style guides within companies can be updated based on the perceptual responses from the results. Being able to know and understand the effects of certain visual designs, products can be visually shown in strategic ways to influence the consumer at hand.

With respect to the study's convergent validity, researchers compared across the tasks to see if there were any relationships between the patterns and colors. For the colors there was a clear overlap between violet hues and green hues with differences for the color yellow. For the patterns there were similarities within lines that are perceived as the fastest across both tasks.

The methodology used in this study has proven adequate to measure differences in speed perception induced by different background or object colors and patterns. However, this study has only quantified the response to 12 colors and 11 patterns but there are still many other shapes and texture combinations along with the various color combinations that could be looked at within this space. Another limitation of the present study is that the degree of immersiveness for the background of the simulated reaction task could not be entirely controlled due to the nature of the online survey. We were unable to regulate the size and screen resolution of each subject's screen so the visual application and experience could have been different for each subject. Thirdly, the recognizable object used in this study was a shoe. Using a shoe could be a confounding factor due to the archetypal aspects that could trigger the thought of movement and the generalization that shoes are worn during movement. Further research should be done using other objects to see if the results vary. However, the methodologies developed for this study have shown significant differences between different patterns and colors, typically a good indication that with minor modifications they could be used to test various hypotheses related to the impact of color, texture and shape on the perception of speed and perhaps other psycho-physiological variables. Overall, being able to understand how humans perceive objects through two dimensional designs and advertisements is an important and useful methodology that can be easily applied to other real-world applications.

## REFERENCES


Agyekum, C. K., Haifeng, H., & Agyeiwaa, A. (2015). Consumer perception of product quality. *Microeconomics and Macroeconomics*, *3*(2), 25-29.

Bailey, R. J., Grimm, C. M., & Davoli, C. (2006). The real effect of warm-cool colors.

Cairns, P., Power, C., Barlet, M., & Haynes, G. (2019). Future design of accessibility in games: A design vocabulary. *International Journal of Human-Computer Studies*, *131*, 64-71.

Chang, D., Dooley, L., & Tuovinen, J. E. (2002). Gestalt theory in visual screen design—A new look at an old subject.

Dijksterhuis, C., de Waard, D., Brookhuis, K., Mulder, B., & de Jong, R. (2013). Classifying visuomotor workload in a driving simulator using subject specific spatial brain patterns. *Frontiers in Neuroscience*, *7*. https://doi.org/10.3389/fnins.2013.00149

Dougherty, R., Press, W., & Wandell, B. (1999). Perceived Speed of Colored Stimuli. *Neuron (Cambridge, Mass.)*, *24*(4), 893–899. https://doi.org/10.1016/S0896-6273(00)81036-3

Dunning, D. (2007). Self-Image Motives and Consumer Behavior: How Sacrosanct Self-Beliefs Sway Preferences in the Marketplace. *Journal of Consumer Psychology*, *17*(4), 237–249. https://doi.org/10.1016/S1057-7408(07)70033-5

Frederick, E. C. (1984). Physiological and ergonomics factors in running shoe design. *Applied ergonomics*, *15*(4), 281-287.

Frederick, E. C. (1986). Kinematically mediated effects of sport shoe design: a review. *Journal of sports sciences*, *4*(3), 169-184.

García-Rubio, M. A., Picazo-Tadeo, A. J., & González-Gómez, F. (2011). Does a red shirt improve sporting performance? Evidence from Spanish football. *Applied Economics Letters*, *18*(11), 1001-1004.

Graham, L. (2008). Gestalt theory in interactive media design. *Journal of Humanities & Social Sciences*, *2*(1).

Griskevicius, V., & Kenrick, D. (2013). Fundamental motives: How evolutionary needs influence consumer behavior. *Journal of Consumer Psychology*, *23*(3), 372–386. https://doi.org/10.1016/j.jcps.2013.03.003

Lindgaard, G., Fernandes, G., Dudek, C., & Brown, J. (2006). Attention web designers:

You have 50 milliseconds to make a good first impression!. *Behaviour & information technology*, *25*(2), 115-126.

Lugo, J. E., Schmiedeler, J. P., Batill, S. M., & Carlson, L. (2015). Quantification of classical gestalt principles in two-dimensional product representations. *Journal of Mechanical Design*, *137*(9).

Manser, M. P., & Hancock, P. A. (2007). The influence of perceptual speed regulation on speed perception, choice, and control: Tunnel wall characteristics and influences. *Accident Analysis & Prevention*, *39*(1), 69-78.

Mentzel, S. V., Schücker, L., Hagemann, N., & Strauss, B. (2019). Perceiving speed—The color can matter. *Color Research & Application*, *44*(6), 957-966.

Mikellides, B. (2012). Colour psychology: The emotional effects of colour perception. In *Colour Design* (pp. 105-128). Woodhead Publishing.

Ratneshwar, S., & Mick, D. G. (Eds.). (2005). *Inside consumption : Consumer motives, goals, and desires*. ProQuest Ebook Central https://ebookcentral-proquest-com.ezproxy1.lib.asu.edu

Shibasaki, M., & Masataka, N. (2014). The color red distorts time perception for men, but not for women. *Scientific reports*, *4*(1), 1-4.

Sylcott, B., Cagan, J., & Tabibnia, G. (2013). Understanding Consumer Tradeoffs Between Form and Function Through Metaconjoint and Cognitive Neuroscience Analyses. *Journal of Mechanical Design (1990)*, *135*(10). https://doi.org/10.1115/1.4024975

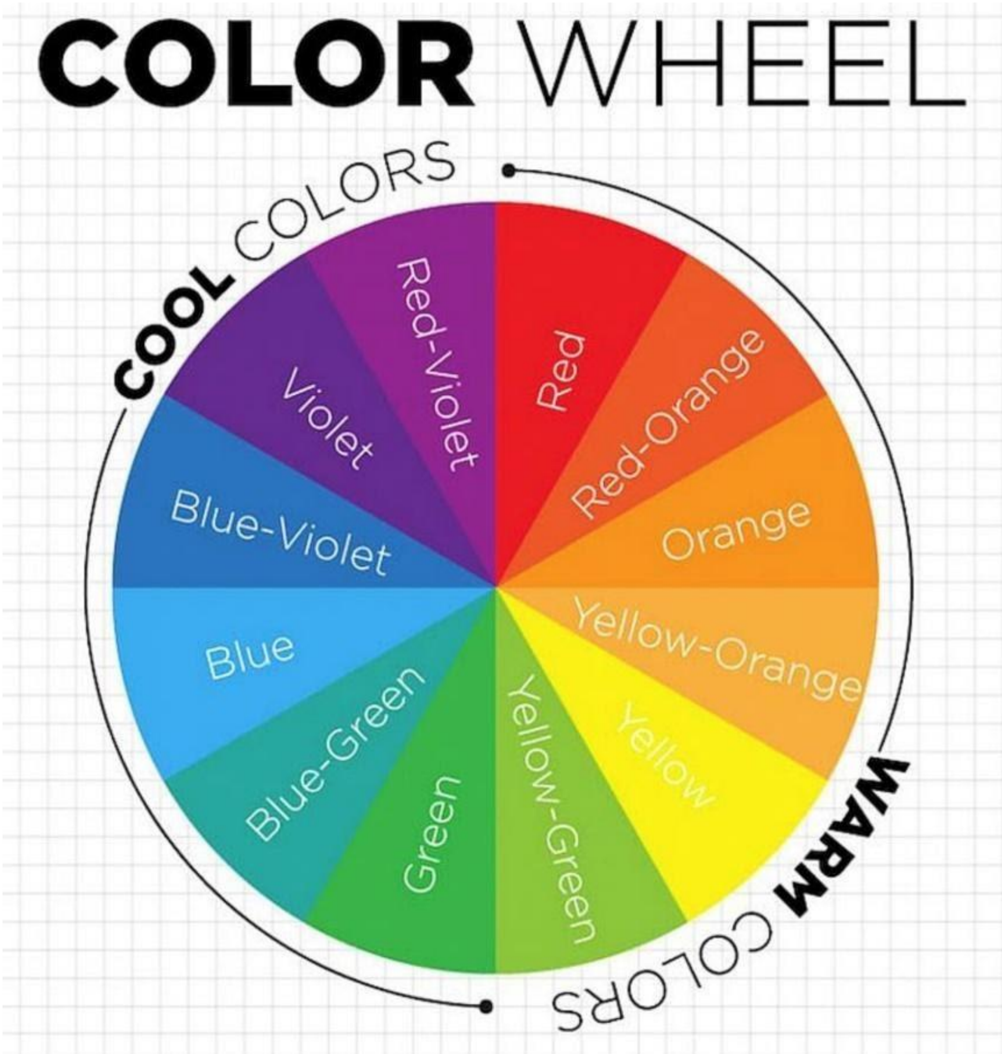
Stone, L. S., & Thompson, P. (1992). Human speed perception is contrast dependent. *Vision research*, *32*(8), 1535-1549.

Valencia-Romero, L. (2016). Part-Worth Utilities of Gestalt Principles for Product Esthetics: A Case\Study of a Bottle Silhouette. *Journal of Mechanical Design (1990)*, *138*(8). https://doi.org/10.1115/1.4033664

Wu F, Fu R, Ma Y, Wang C, Zhang Z (2020) Relationship between speed perception and eye movement—A case study of crash-involved and crash-not-involved drivers in China. PLOS ONE 15(3): e0229650. https://doi.org/10.1371/journal.pone.0229650

# APPENDIX A

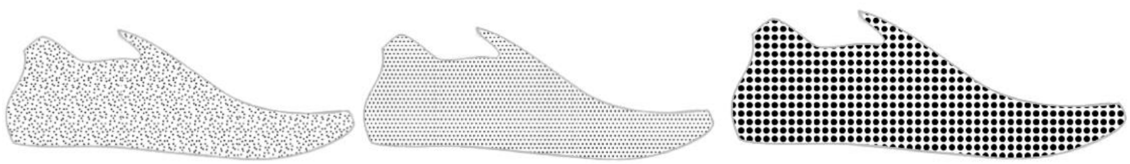
## COLOR WHEEL


COLOR WHEEL
COOL COLORS
WARM COLORS
Red
Red-Orange
Orange
Yellow-Orange
Yellow
Yellow-Green
Green
Blue-Green
Blue
Blue-Violet
Violet
Red-Violet

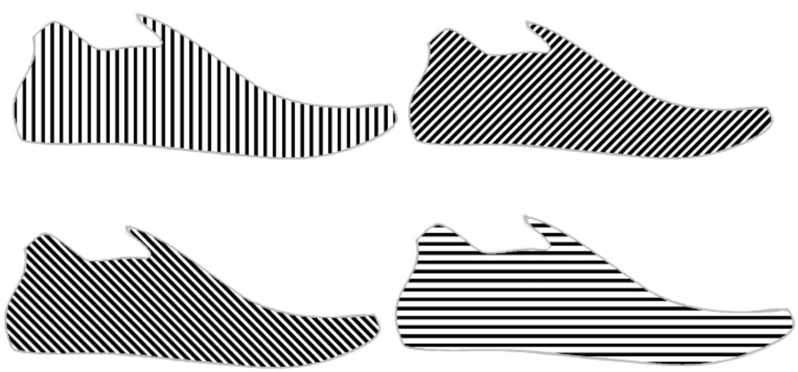
# APPENDIX B

## DISCRIMINATION TASK SILHOUETTES: PATTERNS

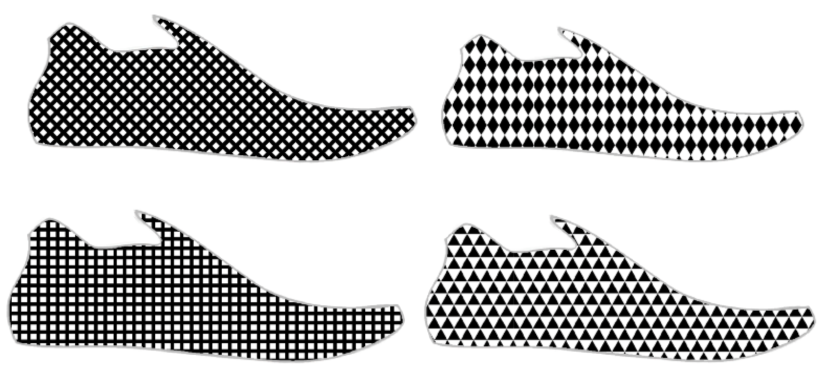
Dots:



Lines:



Planes:

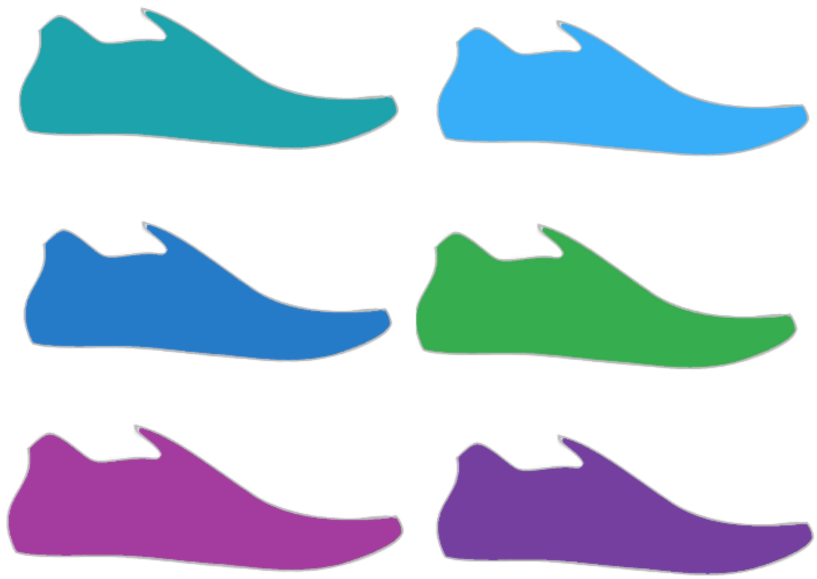


Control:

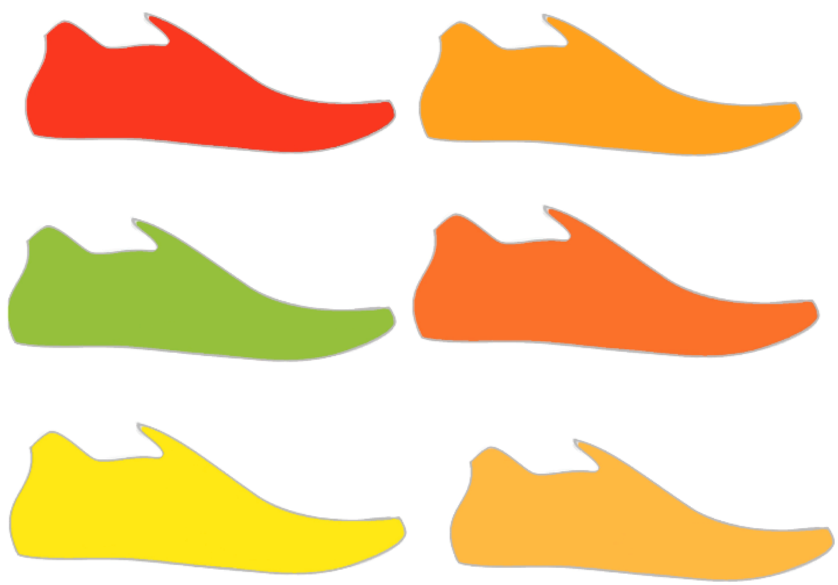
32APPENDIX C

DISCRIMINATION TASK SILHOUETTES: COLORS

Cool Colors:



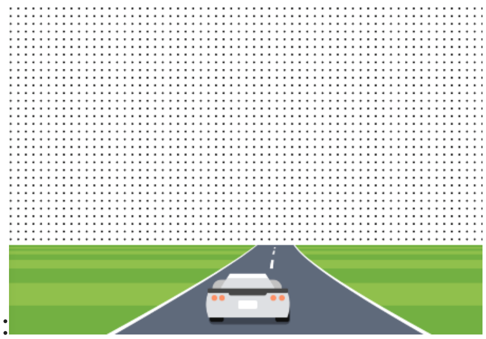
Warm Color:

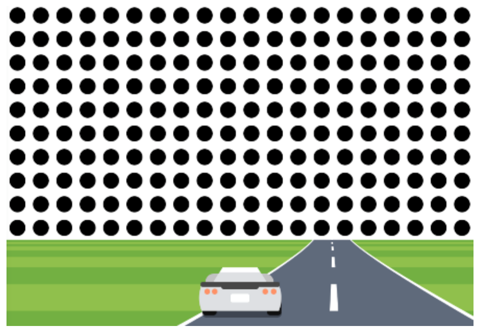


APPENDIX D

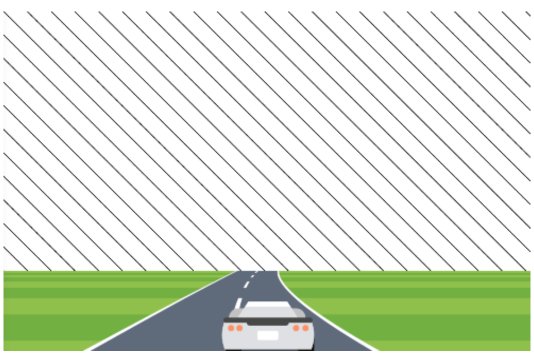
REACTION TASK: PATTERNS

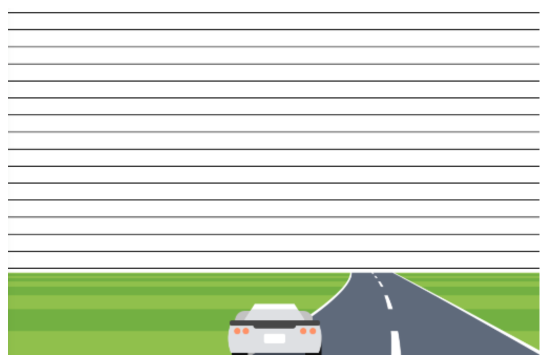
Dots

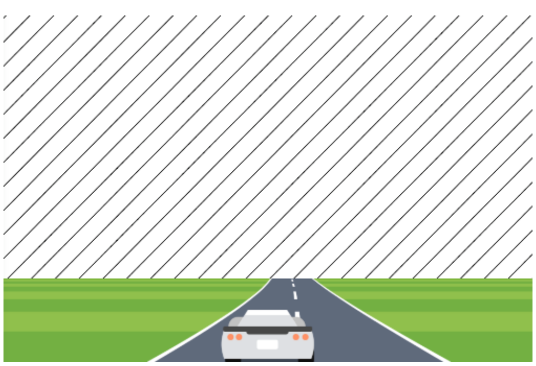


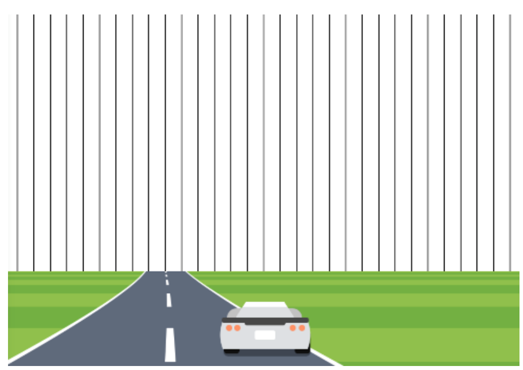


Lines:

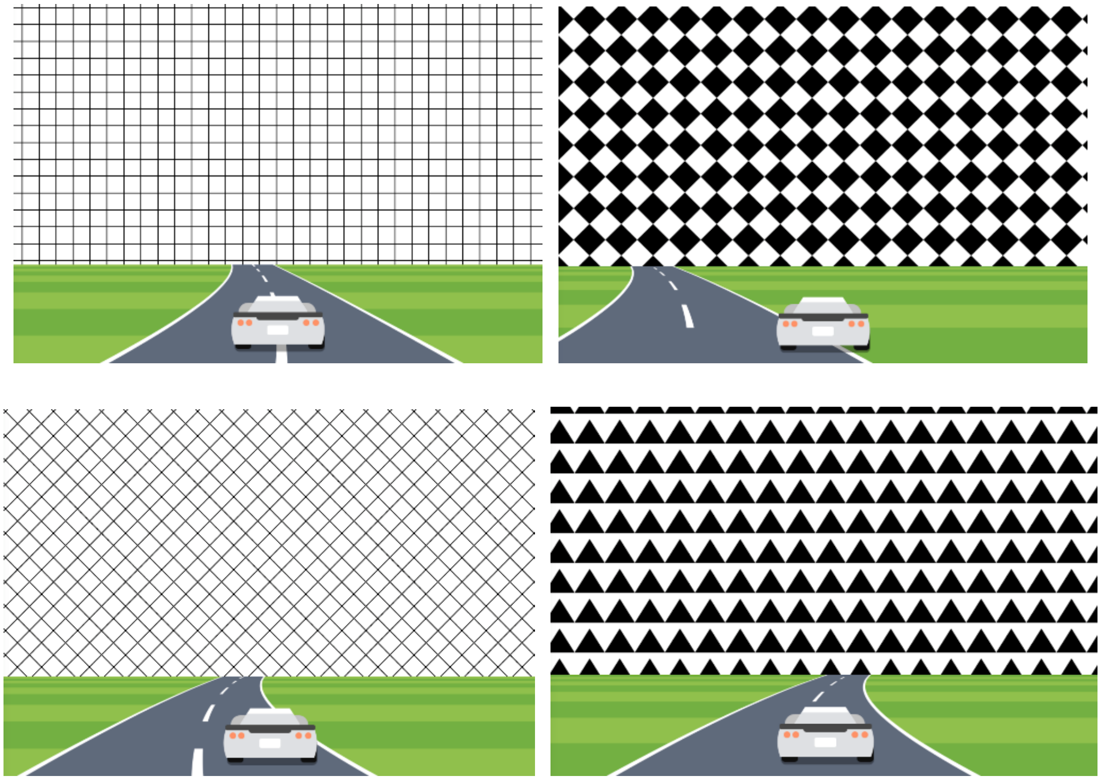








Planes:

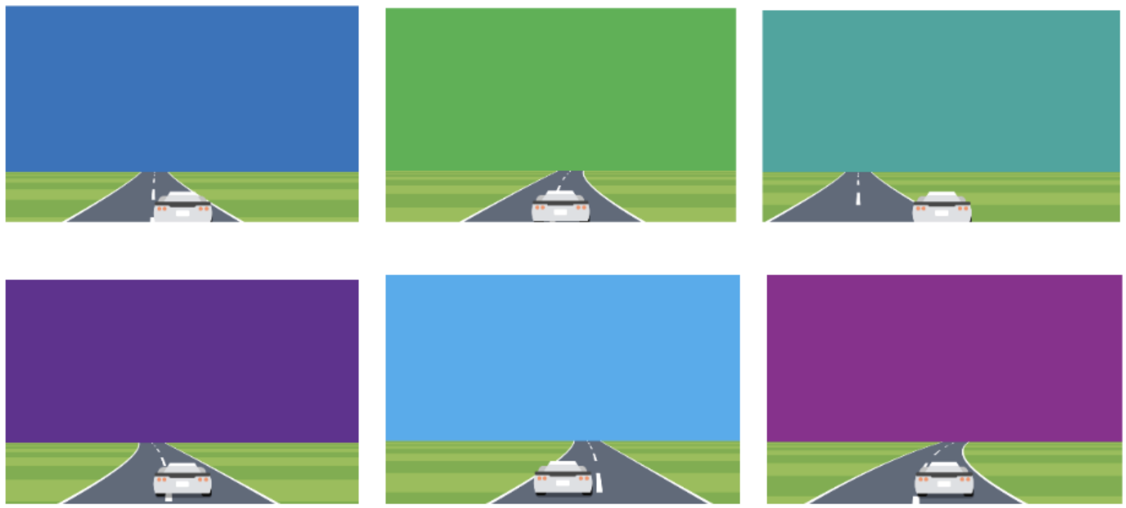


Control:

# APPENDIX E

# REACTION TASK: COLORS

Cool Colors:



Warm Colors: