

The Tie-O-Matic: The analysis and modeling of the cognitive task of tie selection

For partial fulfillment of requirements for
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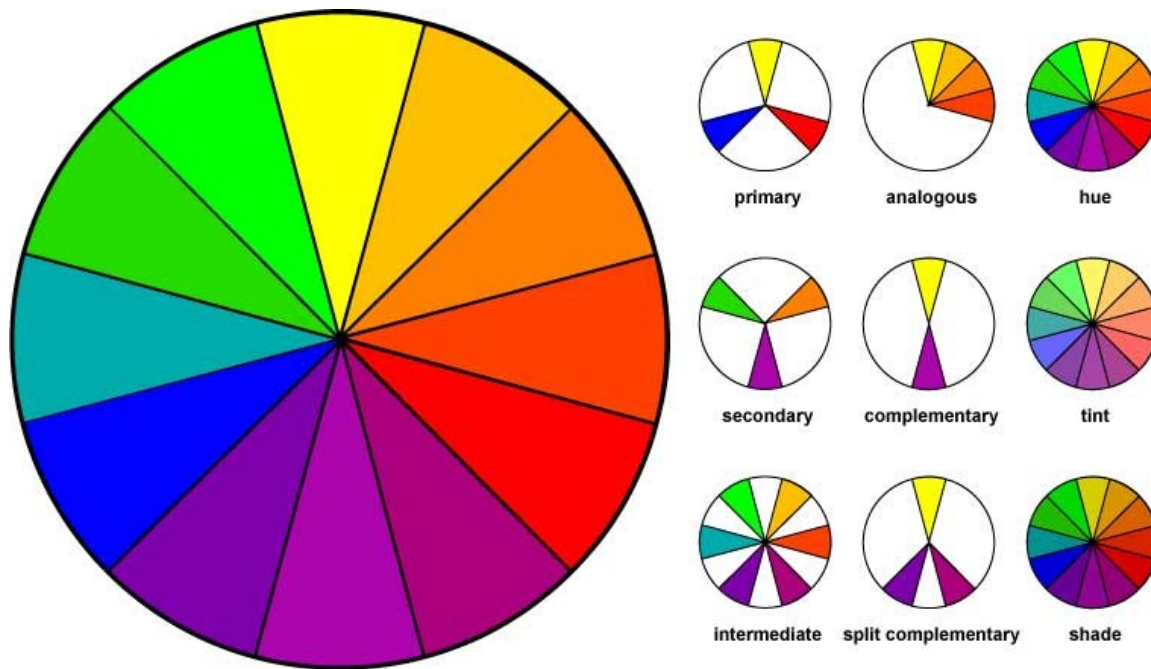
Description

The goal of the project was to analyze and to model the task of tie selection. This task was explored a cognitive task which was tested on human subjects and was also modeled in a computer program. Given 10 different shirts, users were asked to select the best matching tie for each. Behavior for automatic tie selection was then implemented into the application which was used for the cognitive testing.

Background: Color Theory

An abbreviated summary of color and some of the associated theories provides an appropriate background for further exploration of matching shirt and tie colors.

The Color Wheel



Primary Colors: Colors at their basic essence; those colors that cannot be created by mixing others.

Secondary Colors: Those colors achieved by a mixture of two primary colors.

Intermediate Colors: Those colors achieved by a mixture of primaries and secondaries.

Analogous Colors: Those colors that are adjacent to each other on the color wheel. One color is used as a dominant color while others are used to enrich the scheme.

Complementary Colors: Complementary colors are located directly across from each other on the color wheel. The complementary color scheme offers stronger contrast than any other color scheme, and draws maximum attention.

Split-Complementary Colors: A variation of the standard complementary scheme. It uses a color and the two colors adjacent to its complementary. This provides high contrast without the strong tension of the complementary scheme.

Color Schemes

Monochromatic: This scheme is clean and elegant. Monochromatic colors go well together,

producing a soothing effect. Based on analogous colors, the monochromatic scheme is easy on the eyes, especially with blue or green hues.

Triadic: This scheme offers high contrast while retaining harmony. Any combination of the primary hues: red, yellow, and blue; and their tints and shades, can be used to create Triadic color systems.

Tertiary: This (double complementary) scheme is the richest of all the schemes using four colors arranged into two complementary color pairs. One color should be dominant over all, or else the scheme can be difficult to harmonize.

Earth: Earth colors are taken from nature, are warm in temperature, and when used together create an analogous harmony.

Achromatic or Neutral

Combines black, white, and gray hues.

Warm/Cool

Families of analogous colors include *warm colors* (red, orange, yellow), which tend to advance towards the eye, and *cool colors* (green, blue, violet), which tend to retreat.

Seasonal Colors: Autumn colors are rust, brown, green, and burgundy. Wearing rust in the summer, or light yellow in the fall may look out of place.

Color Values: Dark colors recede thus making you look thinner, and light colors project, which tends to bulk you up. Dark colors are more formal-looking than light.

Coordinating Shirts and Ties

Solid colors represent the most authoritative and memorable color choice. However, an entirely monochrome color scheme can be boring.

Shirt and Tie colors should be chosen based on either matching or contrasting.

- A dark blue tie with a pale blue shirt and a blue or gray suit is an example of a harmonious color match.
- The contrast of a navy suit and white shirt traditionally works well with every skin and eye color. Likewise, the classic black and white found in formalwear.

Rule of Two-of-Threes

Whenever a shirt and tie are worn with a jacket, the wearer should follow these rules:

- Two items can be plain or solid colors, the third item should be fancy (striped, patterned, plaid).
- Of three items (shirt, jacket, tie) two should be dark in hue and the third should be light

Plain White Shirts

A white shirt is a blank canvas. Any color tie goes with a white shirt.

Solid Color Shirts

Match the same or analogous color tie with a solid shirt. Select an appropriate complementary color

for contrast. There are many options available

Stripes

View the stripes from a distance and determine the primary or dominant color. Based on the dominant color, add a correspondingly coordinated color. For example, if you see navy blue stripes, add a yellow tie with a box pattern or a pin-dot or polka dots.

Patterns

Analyze patterns based on:

Size (scale)

Type or design (whether it's stripe, polka dots, geometrics, etc.)

Color

Intensity (bold or subtle)

You can mix two or more patterns as long as some of the colors in each match, and the patterns are not the exact same size or type.

Influence of color on the selection of shirts and ties

Although most people may not consult a color chart when selecting items to wear for the day, it is clear human perception of color is a source of visual stimulation, pleasure, and in some cases, distress. The average individual is confronted with a stunning array of choices in terms of shirt and tie colors, patterns, and textures. An individual who arrives to work in well-coordinated attire is generally perceived to be more responsible, effective, and efficient. However, picking out color-coordinated clothing can be a difficult task for many, especially for individuals suffering from color-blindness. Subsequently, if an application can make color choices based on the correct human decision-making "rules" perhaps good taste and color harmony will prevail in the public arena.

Sources for this summary include:

"Coordination". Ask Andy About Clothes. Accessed: 19 Feb 2007.

<http://www.askandyaboutclothes.com/Clothes%20Articles/Coordination.htm>

Grais, Stuart. "Color Schemes". Color Topics online. Accessed: 01 Mar. 2007.

http://facweb.cs.depaul.edu/sgrais/color_topics.htm

Image of Color Wheel found at S. Grais Color Topics online. Accessed: 01 Mar. 2007

http://facweb.cs.depaul.edu/sgrais/color_wheel.htm

"How to Match Ties to Shirts & Suits". The Necktie Aficionado. Accessed: 28 Feb. 2007

<http://www.necktieaficionado.com/How-To-Match.html>

Hypothesis

In the short time span which was to be devoted to the project, it was not expected that we would develop an application fully capable of solving a person's clothing coordination deficiencies. Rather, it was hoped that at least within the limited scope of testing and analysis for the project, our model would be able to provide some statistically relevant results and will show promise as a pilot or case study in

the feasibility of modeling tie selection as a cognitive task. Our working hypothesis for testing of human subjects was that color of shirts and ties would alone provide a significant enough factor in tie selection by human subjects that it could provide the basis for a reasonable model of selection.

Human Testing

A web-based computer program was used to collect and to record the test results. This program displayed 10 shirts and the user was asked to select a tie from a predefined set that best matched each shirt. At the end of each selection the user was asked for information on why they made that choice. Stipulations regarding the collection of test data included the following:

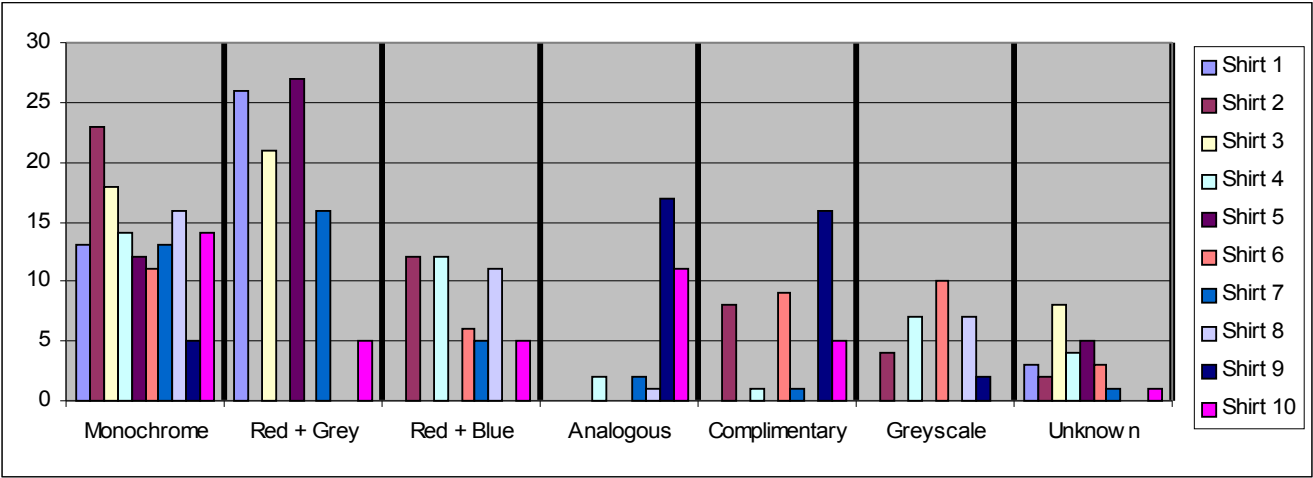
- The data was recorded on a per session basis.
- The data was recorded anonymously, but in a manner which will allow for the determination of which choices were made by a distinct user.
- Ties and shirts were identified by dominant color(s).

The testing results were used as a basis for creating a model for selection of tie and shirt matches. That model was implemented in a program with an interface similar to the testing interface, but which provided the tie selections itself. A sample of the data set is shown in the Appendix A. A summary analysis by shirt is provided in Appendix B.

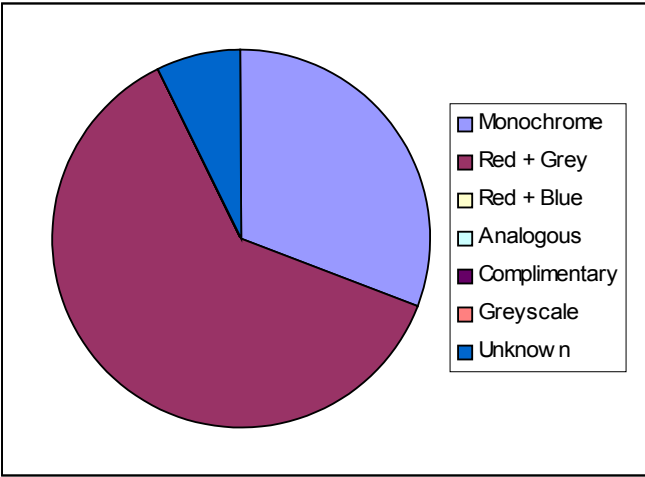
Here is a summary of the human testing results used in the computational model:

- Grey is a neutral color. It has no value for hue or saturation. There was a strong preference to combine this color with the color red at varying levels of brightness. Red coincidentally also has no value for hue. There was also preference to combine grey with grey colors at different values for brightness.
- There was very strong preference for creating a monochrome color scheme with the shirt and tie. This was done in a wide majority of selections, most often with the color blue.
- Complimentary and Analogous color schemes were created, but this was infrequent.
- Little could be determined from this data with regard to the combination of cool and warm colors.

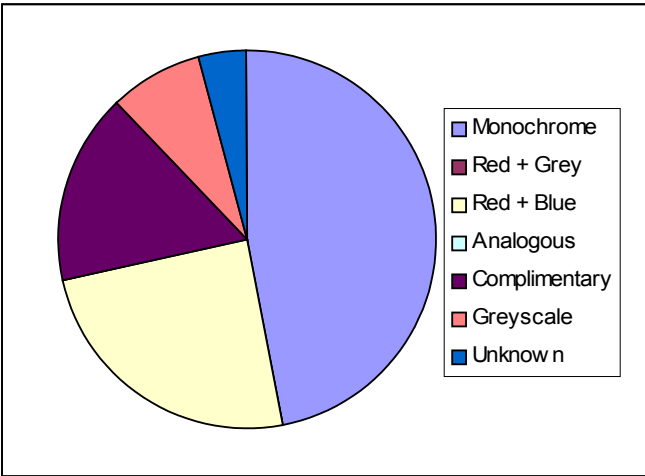
Results of Human Testing Summarized



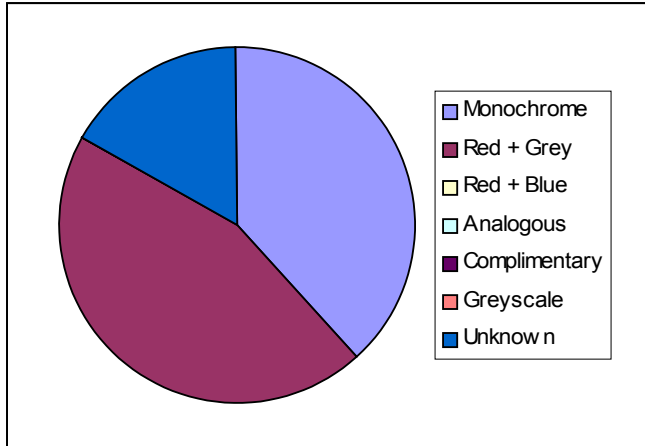
Shirt 1



Shirt 2

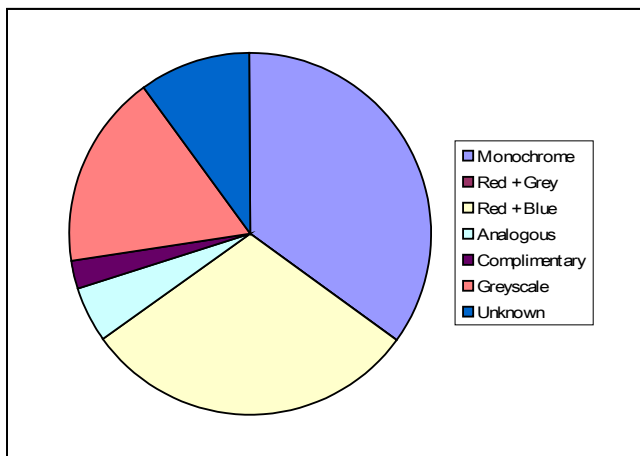


Shirt 3

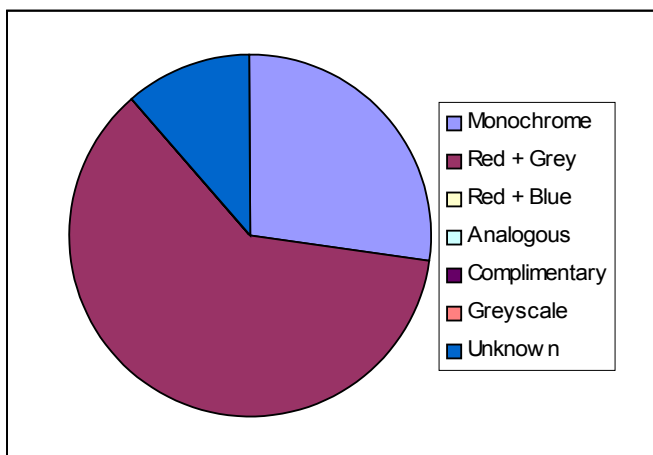


Shirt 4

Shirt 4 has dull blue stripes. Some participants thought the stripes were grey.

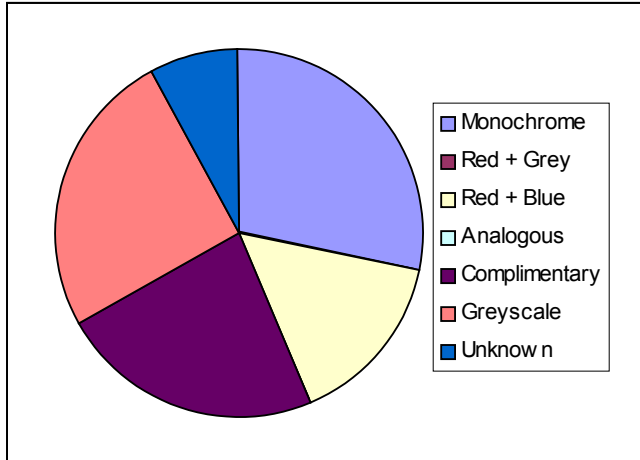


Shirt 5

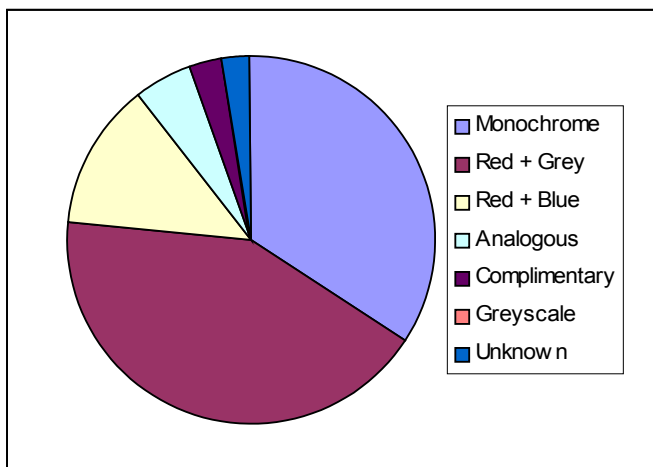


Shirt 6

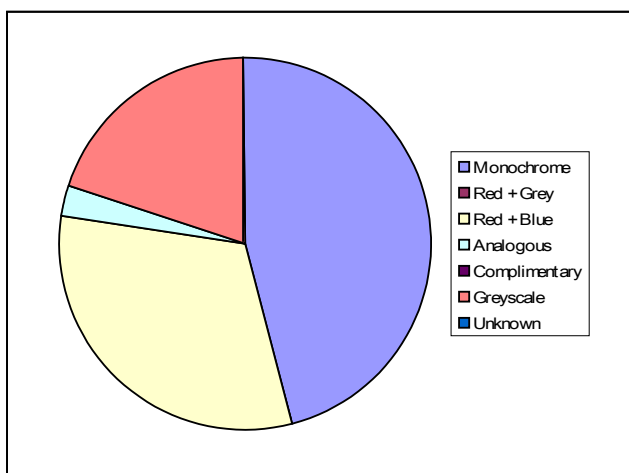
Shirt 6 is blue. Some participants thought the color was grey.



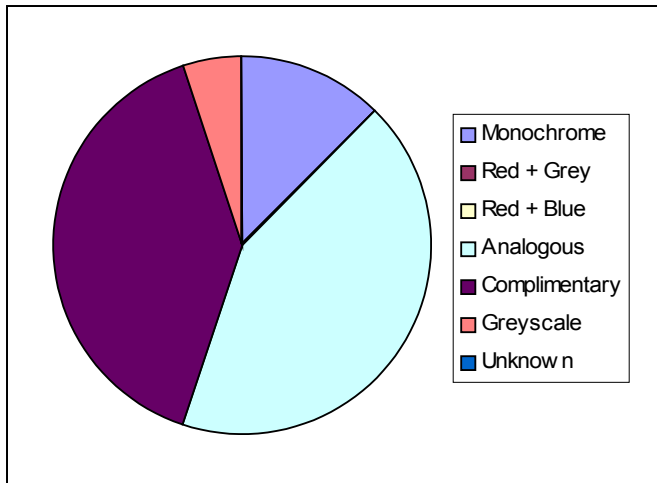
Shirt 7



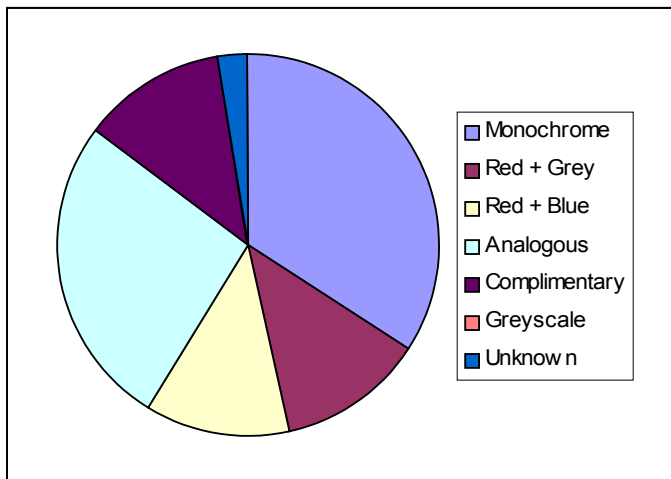
Shirt 8



Shirt 9



Shirt 10



Computational Model

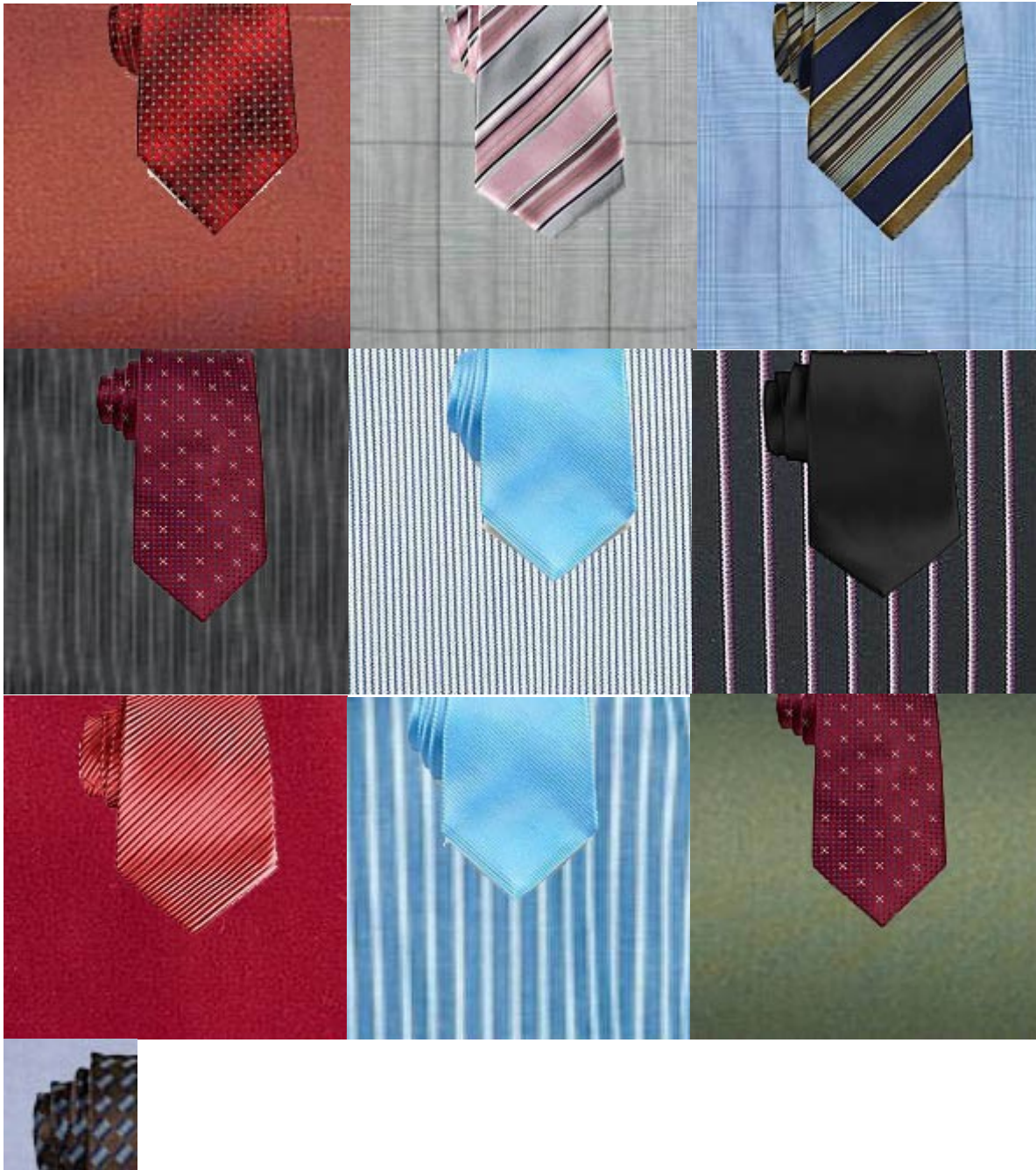
The Computational model is based on color theory and human testing data.

The shirt is question has a relationship to each tie. The attributes of the relations are used to rate the quality of the shirt-tie match. The model was initially developed on color theory alone and then adjusted to address new information discovered during the experiments.

- Identify 3 most dominant colors in each tie in closet
- Identify the overall color distribution for tie
- Identify dominant color in shirt
- Identify applicable color properties
 - a. Identify the color scheme involved in each shirt-tie combination.
 - b. Evaluate the combination of cool and warm colors.
 - c. Evaluate the differences in value and saturation of colors with the same hue.
 - d. Account for simplicity: people tended to prefer simple colors.
 - e. Consider color distribution: in shirts with high color distribution a monochrome pattern may be present and relevant, but not show up using the three dominant colors. When dealing with this case, the ratio of this color to other dominant colors must also be considered in the rating.
- Rate the combination based on the importance of the relationship. The importance is determined based on human data.
- Account for human need for variety: Reduce the rating of selection if it has been chosen before. Don't let it fall to zero. It still may be a good choice.

The Results

The results from the model are:



Comparison of Human Testing and Computational Model

We were successful in providing a close match to human results. The results were not an exact match for human choices, however the choices were similar once the rules and ratings were applied.

Information can be derived from human evaluation results on how these color relationships should be rated. The initial model identified five color schemes; monochrome, analogous, complimentary, dual complimentary and triadic. However, when human testing was complete, the data suggested that complimentary and analogous color schemes were used less frequently and that dual complimentary and triadic color schemes were used infrequently or not at all. Given this information, monochrome color schemes were given the highest rating because humans showed the strongest preference for this scheme in tie selection. Analogous and Complimentary schemes were kept at comparatively low rates. Triadic and Dual Complimentary schemes were not considered in this model.

Humans also showed a strong preference for mixing shades of red with shades of grey. This could be partially accounted for in the model by looking for distance between value and saturation. In this implementation a simple solution was to offset a color that has a value of zero for the hue and saturation with a color that had a zero hue and a non-zero value for the saturation.

From this data set, we did not allow us to derive any information about the combination of warm and cool colors. The shirt choices are mostly responsible. Found images that could provide the highest quality for both viewing by the human test subject and color extraction were used. This set only included one warm color. Given the situation, the rule of color theory for handling warm and cool mix remained in the model, but was not emphasized. Given the human preference for monochrome schemes this did not have an impact on the test results.

In the end we were able to produce a model that came very close to human results. There were a few issues.

- It was by luck we did not have any pattern ‘violations.’ During the testing and development process of the computation model, we had a case of mixing stripes with plaids. Nothing was added to the model to affect the choice of patterns. It was by circumstance that the color selection model chose a tie that did not contain plaids.
- One of our final test results shows a red/magenta tie offering a very nice compliment to green shirt. This was not the intention of the Tie-O-Matic. In this case, the shirt had more grey than green; grey was the dominant color. The color green was not seen, because only one color is used for shirts. The tie chosen has more red pixels than pixels of any other color, however, it also has a lot of magenta pixels. The red dominance combined with the grey in the shirt trumped other matches. It was a fortunate chance that the green and magenta pixels compliment each other.

Possible features for the Tie-O-Matic v 2.0:

Consider pixels in relation to each other.

This would solve both of the issues discovered. Blocks of pixels of the same color that appeared next to each other form a pattern. There might be more than one color involved in the pattern at a high level, but at a low level there must be some relationship between pixels of the same or similar color for the pattern to be discernable. When a significant amount non-grey color pixels are intermingled with a large amount of grey pixels, the grey color should be seen affecting the color, but not as representing the dominant color itself.

As an application, it is questionable whether it is more value to match human results or to apply color theory more strictly. We could conceivably build an application that improves our ability to make a

strong impression with our clothing.

Psychological Implication

We are dealing with a very subjective subject. But there does appear to be some method involved. In the not-so-cog-sci area of psychology, it appears that people tended to make 'safe' choices in clothing, or choices with a low-risk of being mismatch. In choosing the clothes you wear there is always a risk of embarrassment, or of being perceived in as sloppy, unkempt and unprofessional. Choosing contrasting colors could be perceived as bold or distinctive. It could also be perceived as overly flashy or even grotesque. According to color theory, it is more difficult to balance contrasting color schemes.

Appendix A: Sample Tie Selection Data

Full data set includes over 400 rows of data and user comments.

Tue Feb 27 10:52:23 CST 2007	B6DD5F64F8AE14E49D435675C83577AE	tie21	shirt1
Tue Feb 27 11:17:31 CST 2007	8D727C8A7706E8D2A59E78ADF72CD2A6	tie11	shirt1
Tue Feb 27 11:18:05 CST 2007	8D727C8A7706E8D2A59E78ADF72CD2A6	tie37	shirt2
Tue Feb 27 11:18:21 CST 2007	8D727C8A7706E8D2A59E78ADF72CD2A6	tie33	shirt3
Tue Feb 27 11:19:04 CST 2007	8D727C8A7706E8D2A59E78ADF72CD2A6	tie35	shirt4
Tue Feb 27 11:19:22 CST 2007	8D727C8A7706E8D2A59E78ADF72CD2A6	tie37	shirt5
Tue Feb 27 11:19:59 CST 2007	8D727C8A7706E8D2A59E78ADF72CD2A6	tie3	shirt6
Tue Feb 27 11:20:20 CST 2007	B6DD5F64F8AE14E49D435675C83577AE	tie17	shirt2
Tue Feb 27 11:20:37 CST 2007	8D727C8A7706E8D2A59E78ADF72CD2A6	tie38	shirt7
Tue Feb 27 11:21:21 CST 2007	8D727C8A7706E8D2A59E78ADF72CD2A6	tie37	shirt8
Tue Feb 27 11:21:40 CST 2007	8D727C8A7706E8D2A59E78ADF72CD2A6	tie13	shirt9
Tue Feb 27 11:22:15 CST 2007	8D727C8A7706E8D2A59E78ADF72CD2A6	tie17	shirt10
Tue Feb 27 11:22:38 CST 2007	B6DD5F64F8AE14E49D435675C83577AE	tie18	shirt3
Tue Feb 27 11:23:46 CST 2007	B6DD5F64F8AE14E49D435675C83577AE	tie16	shirt4
Tue Feb 27 11:25:33 CST 2007	B6DD5F64F8AE14E49D435675C83577AE	tie9	shirt5
Tue Feb 27 11:26:10 CST 2007	B6DD5F64F8AE14E49D435675C83577AE	tie2	shirt6
Tue Feb 27 11:26:46 CST 2007	B6DD5F64F8AE14E49D435675C83577AE	tie6	shirt7
Tue Feb 27 11:27:27 CST 2007	B6DD5F64F8AE14E49D435675C83577AE	tie3	shirt8
Tue Feb 27 11:28:21 CST 2007	B6DD5F64F8AE14E49D435675C83577AE	tie12	shirt9
Tue Feb 27 11:30:05 CST 2007	B6DD5F64F8AE14E49D435675C83577AE	tie20	shirt10
Tue Feb 27 13:30:49 CST 2007	501A208A4F7C3C1E73AB310085DE83CB	tie40	shirt1
Tue Feb 27 13:38:22 CST 2007	A14B56273EE7A8593EBEE4B28257C8AC	tie3	shirt1
Tue Feb 27 13:39:00 CST 2007	A14B56273EE7A8593EBEE4B28257C8AC	tie9	shirt2
Tue Feb 27 13:39:14 CST 2007	A14B56273EE7A8593EBEE4B28257C8AC	tie18	shirt3
Tue Feb 27 13:40:32 CST 2007	A14B56273EE7A8593EBEE4B28257C8AC	tie16	shirt4
Tue Feb 27 13:42:02 CST 2007	A14B56273EE7A8593EBEE4B28257C8AC	tie6	shirt5
Tue Feb 27 13:43:25 CST 2007	A14B56273EE7A8593EBEE4B28257C8AC	tie1	shirt6
Tue Feb 27 13:43:51 CST 2007	A14B56273EE7A8593EBEE4B28257C8AC	tie18	shirt7
Tue Feb 27 13:44:46 CST 2007	A14B56273EE7A8593EBEE4B28257C8AC	tie24	shirt8
Tue Feb 27 13:45:23 CST 2007	A14B56273EE7A8593EBEE4B28257C8AC	tie23	shirt9
Tue Feb 27 13:48:31 CST 2007	A14B56273EE7A8593EBEE4B28257C8AC	tie27	shirt10
Tue Feb 27 13:59:06 CST 2007	F47201A8DA47A32AA272AA22FB87415F	tie6	shirt1
Tue Feb 27 13:59:32 CST 2007	F47201A8DA47A32AA272AA22FB87415F	tie24	shirt2
Tue Feb 27 13:59:55 CST 2007	F47201A8DA47A32AA272AA22FB87415F	tie6	shirt3
Tue Feb 27 14:00:15 CST 2007	F47201A8DA47A32AA272AA22FB87415F	tie8	shirt4
Tue Feb 27 14:00:46 CST 2007	F47201A8DA47A32AA272AA22FB87415F	tie18	shirt5
Tue Feb 27 14:01:09 CST 2007	F47201A8DA47A32AA272AA22FB87415F	tie9	shirt6
Tue Feb 27 14:01:26 CST 2007	F47201A8DA47A32AA272AA22FB87415F	tie28	shirt7
Tue Feb 27 14:01:47 CST 2007	F47201A8DA47A32AA272AA22FB87415F	tie8	shirt8
Tue Feb 27 14:02:01 CST 2007	F47201A8DA47A32AA272AA22FB87415F	tie36	shirt9
Tue Feb 27 14:02:18 CST 2007	F47201A8DA47A32AA272AA22FB87415F	tie26	shirt10

Appendix B: Data Analysis

Shirt 1:

tie1	tie32	tie8	tie9	tie33	tie4	tie40	tie6	tie11	tie18
tie15	tie32	tie8	tie9	tie33	tie4	tie40	tie6	tie11	tie18
tie21					tie4	tie40	tie6	tie11	tie18
tie22					tie4	tie40	tie6	tie11	tie18
tie3							tie6	tie11	tie18
tie31							tie6		tie18
tie38									tie18
									tie18

tie18	Fairly common thought that red sets off grey -- In our terms Zero Sat and Hue Shirt = Zero Hue Tie		
tie6	Monochromatic		
tie11	Red + grey OR Monochromatic + Red grey combo	Low Sat	
tie 40	Monochromatic		
tie 4	Red + grey OR Monochromatic + Red grey combo	Low Sat	

Shirt 2:

tie1	tie13	tie24	tie30	tie32	tie37	tie38	tie5	tie16	tie17	tie18	tie25	tie28	tie39
tie10	tie13	tie24	tie30	tie32	tie37	tie38	tie5	tie16	tie17	tie18	tie25	tie28	tie39
tie2								tie16	tie17	tie18	tie25	tie28	tie39
tie26													
tie31													
tie33													
tie6													
tie8													
tie9													

Blue

tie 16	Brown, Blue Subordinate	warm	monochrome in subordinate blue
tie 17	Yellow, Blue Subordinate	warm	Yellow is perfect compliment subordinate color is mono
tie 18	Solid Red	warm	
tie 25	Monochromatic + Neutral		
tie 28	Monochromatic		
tie 39	Monochromatic + Neutral		
tie 5	Shades of Red	warm	
tie 13	Monochromatic		
tie 24	Monochromatic		
tie 30	Brown, Blue Subordinate	warm	some of the blue is complimentary
tie 32	Monochromatic		
tie 37	Monochromatic		
tie 38	Monochromatic		

Other Comments:

Brown is Red at lower saturation

No hue low sat

Red, Blue and Yellow are a part of a Triad on the artist color wheel, but they don't appear in the same combo

Yellow is blues compliment on RGB color wheel

Shirt 3:

tie1	tie12	tie3	tie9	tie11	tie40	tie6	tie17	tie4	tie18
tie25	tie12	tie3	tie9	tie11	tie40	tie6	tie17	tie4	tie18
tie26			tie9	tie11	tie40	tie6	tie17	tie4	tie18
tie28						tie6	tie17	tie4	tie18
tie33								tie4	tie18
tie35									tie18
tie39									tie18
tie8									

tie 18 Red + grey OR Monochromatic + Red grey combo High Sat

tie 4 Red + grey OR Monochromatic + Red grey combo Low Sat

tie 17 Yellow Dom, Blue sub
tie 6 Monochromatic

tie 40 Monochromatic
tie 11 Red + grey OR Monochromatic + Red grey combo Low Sat
tie 9 Red + grey OR Monochromatic + Red grey combo Low Sat

tie 3 Monochromatic
tie 12 Red + grey OR Monochromatic + Red grey combo High Sat

Shirt 4:

tie1	tie8	tie9	tie11	tie22	tie23	tie3	tie33	tie18	tie24	tie6	tie16	tie38
tie13	tie8	tie9	tie11	tie22	tie23	tie3	tie33	tie18	tie24	tie6	tie16	tie38
tie14								tie18	tie24	tie6	tie16	tie38
tie35											tie16	tie38
tie36												tie38
tie37												
tie39												
tie5												

tie 38 Monochromatic

tie 16 Brown, Blue Combo monochrome in subordinate blue

tie 6 Neutral
tie 24 Monochromatic
tie 18 Solid Red

tie 33
tie 3
tie 23
tie 22
tie 11
tie 9
tie 8

Shirt 5:

	tie26	tie5	tie4	tie11	tie18	tie6	tie9
tie20	tie26	tie5	tie4	tie11	tie18	tie6	tie9
tie24			tie4	tie11	tie18	tie6	tie9
tie17					tie18	tie6	tie9
tie31					tie18	tie6	tie9
tie37							tie9
tie38							tie9
tie7							tie9
tie8							tie9

Tie 9	Monochrome with black out of picture
Tie 18	Monochrome with black out of picture
Tie 6	Monochrome with black included

Shirt 6:

tie12	tie13	tie25	tie28	tie30	tie9	tie1	tie16	tie10	tie37	tie38
tie2	tie13	tie25	tie28	tie30	tie9	tie1	tie16	tie10	tie37	tie38
tie3						tie1	tie16	tie10	tie37	tie38
tie32								tie10	tie37	tie38
tie33									tie37	tie38
tie35										tie38
tie36										tie38
tie4										

tie 38	Monochrome
tie 37	Monochrome
tie 10	Yellow and Blue Mix Blue is mono

Shirt 7:

	tie12	tie28	tie32	tie3	tie26	tie6
tie10	tie12	tie28	tie32	tie3	tie26	tie6
tie5				tie3	tie26	tie6
tie14					tie26	tie6
tie18					tie26	tie6
tie21						tie6
tie23						tie6
tie24						tie6
tie33						tie6
tie35						tie6
tie36						
tie38						
tie40						
tie7				tie 6	Black (greyscale) + red monochrome	
tie8				tie 26		

Shirt 8:

tie11	tie32	tie1	tie16	tie25	tie28	tie38	tie9	tie37	tie6	tie18	tie24
tie12	tie32	tie1	tie16	tie25	tie28	tie38	tie9	tie37	tie6	tie18	tie24
tie13								tie37	tie6	tie18	tie24
tie19										tie18	tie24
tie39											tie24
tie4											tie24
tie5											
tie8											
tie3											
		tie 24	monochromatic								
		tie 18	Red								
		tie 6	Black								
		tie 37	Grey								
		tie1	Monochrome								
		tie32	Monochrome								
		tie9									
		tie16	Brown, Blue		blue is analogous						
		tie25	neutral								
		tie28	Monochrome								
		tie38	Monochrome								

Shirt 9:

tie36	tie2	tie15	tie33	tie10	tie7	tie23	tie17
tie4	tie2	tie15	tie33	tie10	tie7	tie23	tie17
tie40			tie33	tie10	tie7	tie23	tie17
tie12					tie7	tie23	tie17
tie13						tie23	tie17
tie21							tie17
tie22							tie17
tie8							tie17
tie9							tie17
tie27							
tie32							

Tie 17	Analogous
Tie 23	Monochrome
Tie 7	Highly Analogous - on either side
tie 10	Highly Analogous - on either side
Tie 33	Highly Analogous - on either side

Shirt 10:

tie13	tie22	tie20	tie27	tie12	tie38	tie8	tie5	tie3	tie26	tie14
tie31	tie22	tie20	tie27	tie12	tie38	tie8	tie5	tie3	tie26	tie14
tie33							tie5	tie3	tie26	tie14
tie36									tie26	tie14
tie37									tie26	tie14
tie23										
tie25										
tie21										
tie17										
tie2										
tie28										

tie 26	Analogous
tie 14	Analogous
tie 3	Grey
tie 5	Analogous