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The Effect of Color on Reaction Times for Shapesplosion Game

Abstract

The purpose of this study was to observe how color would affect reaction time in the Shapesplosion game. *Shapesplosion* is a game that measures reaction time as the gamer attempts to match various shapes to their corresponding box. There are two different types of games. Game one (same shape same color) matches 24 blue colored shapes to 24 blue colored boxes, and game two (same shape different color) matches 24 shapes of 24 different colors to 24 different color boxes. Our intention was to test the problem "Does color interfere with the time it takes to complete the game?". The null hypothesis is that the two groups will not vary in reaction time. The alternative hypothesis is that group two will have a greater reaction time. Upon completion of this study we found that the color of the shapes impacts the reaction time of the game.

Introduction

J. Stroop was a psychologist studying cognition and interference. His findings are discussed in "Studies of Interference in Serial Verbal Reactions," *Journal of Experimental Psychology.* Stroops objective was to study the interference of color when conflicting stimuli - specifically wanted to observe reaction time for verbal reactions [1]. The name of one color printed in the ink of another color -- a word stimulus and a color stimulus was given to a subject. His work followed the work of other psychologists studying inhibition. For example, Munsterberg who studied the inhibiting effects of changes in common daily habits found that a "given association can function automatically even though some effect of a previous contrary association remains" [1]. Two other psychologists - Muller and Schumann- found that "in acquiring associations there is involved an inhibitory process which is not a mere result of divided paths but has some deeper basis yet unknown" [1]. Experiment 2 conducted by J. Stropp was a RDNd (reading color names where the color of the print and the word are different) test where colors of the print of the series of names were to be called in succession ignoring the color named by the words. [1] Stroop's explanatory variable was color of print and the response variable was the time in seconds taken to read a sheet. Half of the subjects read in the order NC (naming color), NCWd (naming color test where the color of the print and word are different), NCWd, and NC. The other half of the subjects read in the order NCWd, NC, NC, NCWd[1]. Variables that were held constant include the number of sheets read and where the subjects were seated. Nuisance factors include an individual's visual cues and ability to focus. 100 total trials were ran for experiment two. From experiment 2, Stroop was able to conclude that conflicting word stimuli does have an effect on the verbal reaction time as there as a 47.0 second increase in average response time[1].

Our experiment checked for the effect color had on reaction time of completing the shapesplosion game. The event of interest in our experiment is completing shapesplosion. The time-to-event random variable is how long it takes to finish the game - the game begins when user clicks “new game”. The variable time was measured in seconds. In order to assure that color was the only variable to account for differences in reaction time, we held the following variables constant: number of shapes to match, environment the game was played in - second floor shapiro undergraduate library, and the age of players - 18 to 22. Regardless of these controlled conditions, unwanted variability may have arose from the use of different devices (laptops/computers), mouses vs trackpad, or rounding errors in the timer. Conditions that would be considered normal include an environment that is not too quiet or too loud, the use of an individual’s personal device, and the elimination of practice rounds in playing the game. These conditions were controlled by the scientist who assessed the game. A change in the normal variable would affect the subjects performance thus skewing the data by potentially increasing reaction times. It is very important to randomize the order in which the games are played to avoid any bias. A few nuisance factors were still present - the time of day the game was played, an individual’s alertness while playing the game, and an individual’s ability to distinguish color. If given the opportunity to speak to a cognitive psychologist or statistician, we would like to gain more insight on what possible disorders people may have in vueing color (ex. Color blindness) and the effect age could have on viewing color.

The goals of our experiment were to observe if color impacted one’s completion time of shapesplosion, because these findings helped us learn more about the Stroop effect. Similar to Stroop who observed that a name of a color when printed in a color that is not denoted by the name is resulted in a different reaction time, we wanted to observe if matching a shape that has a different color block results in a different reaction time than if the color was the same. Our hypothesis was that there is no difference in reaction times and that color does not have an influence on times. After conducting several tests we ended up rejecting our null hypothesis and concluding that a difference in colors results in a difference in reaction times; the reaction times for the same color game and different color game was significantly different.

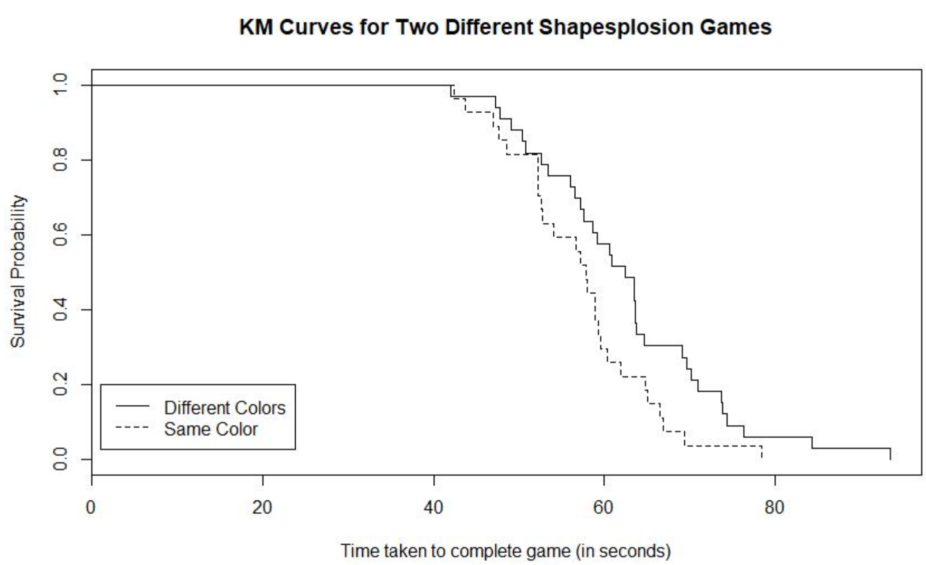
Materials and Methods

60 participants were randomly allocated to the two groups (participants asked to flip a coin: heads - group one (same shape same color), tails - group two (same shape different color)). Group one consisted of 27 participants and group two consisted of 33 participants. Subjects were called individually to the second floor undergraduate library where they were informed to pull out their laptop as the experimenter pulled up the shaplesposion game. Experimenters informed the participant “this is a matching game in

which you must match the shapes to its respective block. Complete this as fast as you can. Your time begins once you click ‘new game’”. Data (time, user, game played, etc) was collected by the site itself, which was later viewed as a CSV file. 60 total trials were run - 27 with the same shape same color, and 33 with the same shape but different color. Practice trials were not given to participants. We attempted to randomize trials as much as possible in order to avoid any potential bias. Despite our attempt, trials cannot be completely randomized as we need to account for subject variability and other nuisance factors including the use of a mouse/trackpad. Our experimental design builds on previous research regarding the interference of color in various situations.

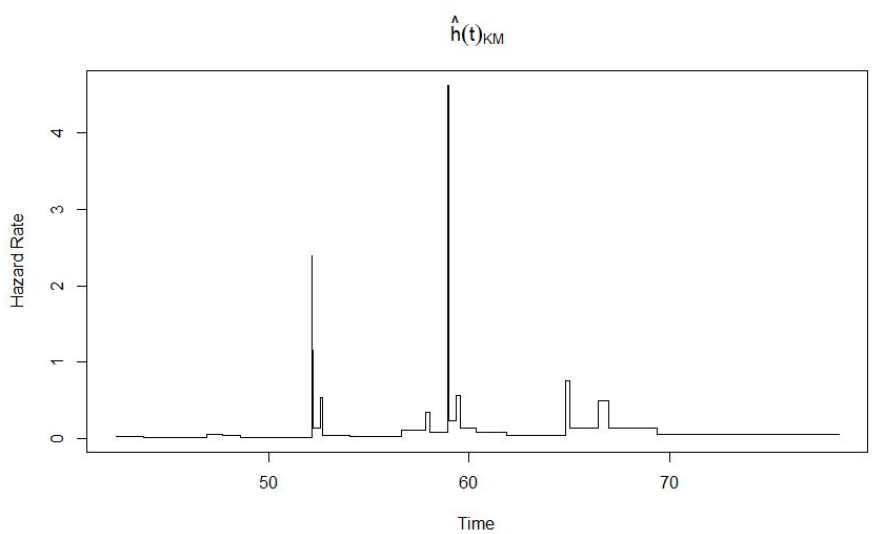
Results

Our question that we tested for was: “Does color interfere with the time it takes to complete the game?” We tested for this by having 60 participants be randomly placed into two different groups based on a flip of a coin. One group played the shapesplosion with all the shapes being the same color, and the other group played the shapesplosion with all the shapes being different colors, and those colors did not match their respective block. For the same color data set, our fastest time was: 42.40 seconds, our longest time was: 78.41 seconds, and our average time was: 57.22 seconds. For the different color data set, our fastest time was: 41.95 seconds, our longest time was: 93.42 seconds, and our average time was: 62.44 seconds. So the difference between our two mean times was 5.22 seconds, with the same color group being faster.

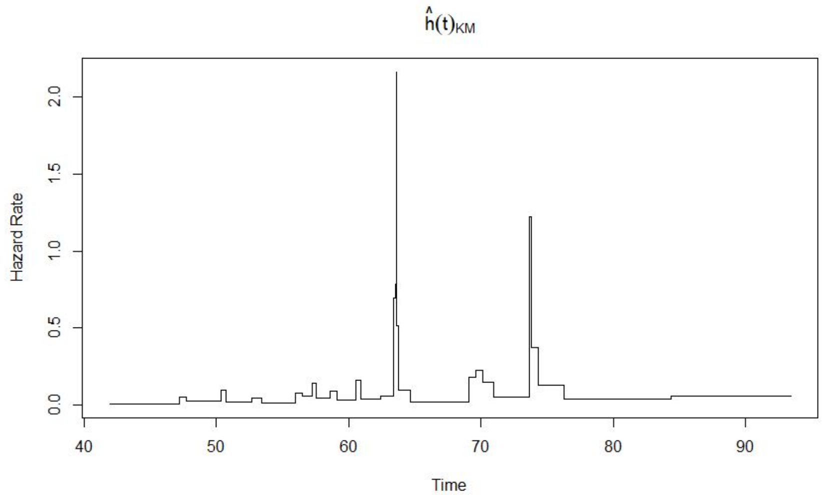


After observing the Kaplan Meier curve show above, we see that the group with different colors tends to be the outer curve which means that it takes longer to complete this game than the same color game. This agrees with the mean calculations previously stated. For both the same and different colors groups, the survival probability is 1 for games that were played in about 42 seconds or less. The survival probability starts to decline for both groups at about 42 seconds. Both groups start to decline more steeply at around 58 seconds and the survival probability declines faster at this point. Then at around 62 seconds the survival probability starts to become more steady again and slow down a little bit more for both groups. Overall, the survival probability for different colors has a higher survival probability than same colors. Also the different colors group has a longer completion time. The data stops at about 79 seconds for same color, but it stops at around 93 seconds for different color group. The survival probability becomes 0 at around 66 seconds for the same color group, and around 83 seconds for the different color group. The survival curve for the same colors group is lower than the different colors group which suggests that the reaction times for the same colors group is faster than the different colors group.

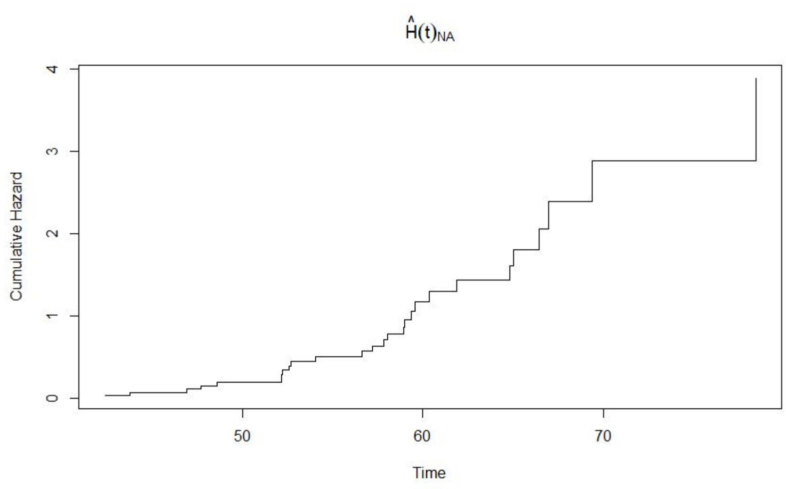
To further examine the risks of game completion for the two different games, we plotted hazard functions for the two different groups. The hazard function plot for the same color game is shown below.



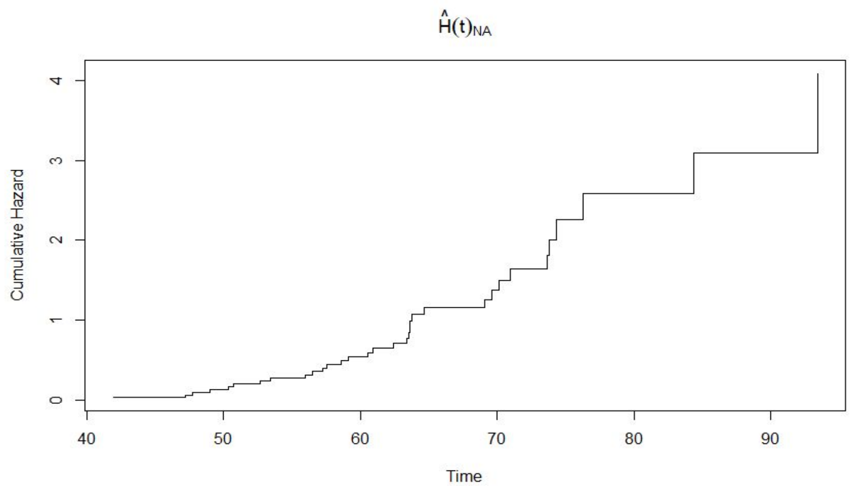
A higher hazard rate is interpreted as a higher chance of completion at that time. So as shown by the peaks of the graph, the game is most likely to be completed at around 52 or 59 seconds, with the biggest peak being 59 seconds. Other times where the game are likely to be completed include 53, 65, and 67 seconds, as shown by the smaller peaks.



The hazard function plot for the different color game is shown above. As shown by the peaks of this this graph, the times where the game is most likely to be finished are 63 and 73 seconds, with the biggest peak being 63 seconds. The same color hazard function has the highest hazard rate at 59 seconds while the different color hazard function has the highest hazard rate at 63 seconds. The same color hazard function having a lower time for the highest hazard rate is consistent with our findings that the same color game takes less time to finish than the different color game.



The cumulative hazard function plot for the same color is shown above. The biggest increases in cumulative hazard for the same color function are around 52-53, 59, 65, and 67 seconds, which parallels our peaks in the estimated hazard function for the same color function.



The cumulative hazard function plot for the different colors is shown above. The biggest increases for the cumulative hazard function of the different color game are around 63 and 73 seconds, which parallels our peaks in the estimated hazard function.

We then performed a formal log-rank and Wilcoxon test to determine if the survival experiences of the individuals in the two different games are significantly different. We wanted to see if the difference in times was significantly different, or just due to sampling variability. Our null hypothesis for both tests is that there would be no difference in time-to-completion between the two games.

Our log-rank test gave us a chi-square value of 4.3 on 1 df, which gave us a p-value of 0.0372. This p-value is lower than our significance level of 0.05 so we reject our null hypothesis that there was no difference between each game, in favor of the alternative hypothesis that there is a difference in time-to-completion between the two games.

However, from the Wilcoxon test, get a chi-square value of 3.5 on 1 df, which gave us a p-value of 0.0626. This is higher than our significance level of 0.05 so we fail to reject the null hypothesis and are unable to conclude that there is a difference in time-to-completion between the two games.

With the log-rank test and the Wilcoxon test giving us contradicting answers, we need further analysis to decide which to use. We know that the Wilcoxon test is better at figuring out differences in the beginning of the Kaplan Meier curve, and the log rank test is better at figuring out differences near the end of the KM curve. So because the p-value for the log-rank test is less than the p-value for the Wilcoxon test, we think this has to do with the KM curve. The KM curves for the two games are closer in the beginning, but are further apart by the end. Because there are not many differences in the beginning, the Wilcoxon test gave us a p-value which is not significant. However, the log rank test gave us a p-value that was significant because by the end of the KM curves, they are much further apart. After this analysis, we decided to go with the log-rank test because logically, it makes sense that the KM curves were closer at first and then slowly split apart. This is because regardless of what game is being played, nobody finishes in the first 40 seconds. So by analyzing the first part of the curves, it is hard to distinguish between the two games.

From the log-rank test we concluded that there is a difference in completion times for the different colors and same colors game, by rejecting the null hypothesis. We kept a lot of conditions constant during our experiment. Some of these constant conditions included number of shapes to match, environment in which the game was played, and age of players. We kept these conditions constant so that we can attribute any differences in our results to be due to the sole difference between the two games, which is the colors of the shapes. So because the colors of the shapes were the only difference between the games, it suggests that the reaction times for the same colors group is faster than the different colors group, due to the color difference.

Our findings build on the work of Stroop and other psychologists who observed a delay in reaction time with various interfering variables. Like Stroop, who observed a delay in reaction time when a name name of a color is printed in a color that is not denoted by the name, we observed a delay in reaction time when color was used as an interfering variable during the game of Shapesplosion.

Appendix

```
> View(PerfectionFlash_data_8_)
> library(survival)
> KM.obj <-
survfit(Surv(PerfectionFlash_data_8_$timeUsed)~PerfectionFlash_data_8_$matchingScheme,
data = PerfectionFlash_data_8_)
> plot(KM.obj, lty=1:2, xlab = "Time taken to complete game (in seconds)", ylab = "Survival
Probability", ylim = c(0,1), main = "KM Curves for Two Different Shapesplosion Games")
> legend(1,.2, c("Different Colors", "Same Color"), lty=1:2)
> SameColor <- subset(PerfectionFlash_data_8_, PerfectionFlash_data_8_$matchingScheme
== "shape")
> DiffColor <- subset(PerfectionFlash_data_8_, PerfectionFlash_data_8_$matchingScheme ==
"diffColor")
> View(SameColor)
> View(DiffColor)
> KM.obj1 <- survfit(Surv(SameColor$timeUsed)~1, data = SameColor)
> KM.obj2 <- survfit(Surv(DiffColor$timeUsed)~1, data = DiffColor)
> plot.haz <- function(KM.obj, plot="TRUE") {
+   ti <- summary(KM.obj)$time
+   di <- summary(KM.obj)$n.event
+   ni <- summary(KM.obj)$n.risk
+   #Est Hazard Function
+   est.haz <- 1:(length(ti))
+   for (i in 1:(length(ti)-1))
+     est.haz[i] <- di[i]/(ni[i]*(ti[i+1]-ti[i]))
+   est.haz[length(ti)] <- est.haz[length(ti)-1]
+
+   if (plot=="TRUE"){
+     plot(ti,est.haz,type="s",xlab="Time",
+          ylab="Hazard Rate",
+          main=expression(paste(hat(h),(t)[KM])))
+   }
+   return(list(est.haz=est.haz, time=ti))
+ }
> plot.haz(KM.obj1, plot= "TRUE")
$est.haz
 [1] 0.02695563 0.01211387 0.05312085 0.04604052 0.01219587 2.39234450 1.16144019
0.13623978 0.53705693 0.04155240
[11] 0.02272056 0.10665529 0.11074197 0.34843206 0.08325008 4.62962963 0.22899015
0.56179775 0.14029181 0.08122157
[21] 0.04844257 0.75757576 0.14306152 0.49115914 0.13689254 0.05532810 0.05532810
```

```
$time
 [1] 42.400 43.774 46.949 47.702 48.607 52.172 52.191 52.232 52.599 52.697 54.034 56.623
57.209 57.811 58.016 58.940
[17] 58.958 59.355 59.533 60.325 61.864 64.813 65.033 66.431 66.940 69.375 78.412

> plot.haz(KM.obj2, plot= "TRUE")
$est.haz
 [1] 0.005769808 0.054920914 0.025581336 0.024527839 0.094215187 0.018649758
0.047241119 0.015142338 0.075329567
[10] 0.058275058 0.140706346 0.044519633 0.090358724 0.034129693 0.159489633
0.035796105 0.059357749 0.694444444
[19] 0.784313725 2.164502165 0.516262261 0.094589482 0.020712939 0.180831826
0.225377507 0.148809524 0.052080621
[28] 1.225490196 0.372439479 0.131095962 0.041315485 0.055072145 0.055072145

$time
 [1] 41.953 47.205 47.774 49.035 50.394 50.760 52.675 53.459 55.999 56.530 57.245 57.554
58.575 59.102 60.567 60.897
[17] 62.449 63.440 63.530 63.615 63.648 63.797 64.678 69.067 69.620 70.113 70.953 73.696
73.832 74.369 76.276 84.344
[33] 93.423

> plot.chaz <- function(KM.obj, plot= "TRUE") {
+   ti <- summary(KM.obj)$time
+   di <- summary(KM.obj)$n.event
+   ni <- summary(KM.obj)$n.risk
+   #Est Cummulative Hazard Function
+   est.cum.haz <- 1:(length(ti))
+   for(i in 1:(length(ti)))
+     est.cum.haz[i] <- sum(di[1:i]/ni[1:i])
+   plot.chaz <- 1:length(KM.obj$time)
+   for (i in 1:length(plot.chaz))
+     plot.chaz[i] <- sum((KM.obj)$n.event[1:i]/(KM.obj)$n.risk[1:i])
+   if (plot=="TRUE") {
+     plot((KM.obj)$time,plot.chaz,type="s",xlab="Time",
+          ylab="Cumulative Hazard",main=expression(paste(hat(H),(t)["NA"])))
+   }
+   return(list(est.chaz=plot.chaz, time=(KM.obj)$time))
+
+ }
> plot.chaz(KM.obj1, plot = "TRUE")
$est.chaz
```

```
 [1] 0.03703704 0.07549858 0.11549858 0.15716524 0.20064350 0.24609805 0.29371710
0.34371710 0.39634868 0.45190423
[11] 0.51072776 0.57322776 0.63989443 0.71132300 0.78824608 0.87157941 0.96248850
1.06248850 1.17359961 1.29859961
[21] 1.44145675 1.60812342 1.80812342 2.05812342 2.39145675 2.89145675 3.89145675

$time
 [1] 42.400 43.774 46.949 47.702 48.607 52.172 52.191 52.232 52.599 52.697 54.034 56.623
57.209 57.811 58.016 58.940
[17] 58.958 59.355 59.533 60.325 61.864 64.813 65.033 66.431 66.940 69.375 78.412

> plot.chaz(KM.obj2, plot = "TRUE")
$est.chaz
 [1] 0.03030303 0.06155303 0.09381109 0.12714443 0.16162719 0.19734147 0.23437851
0.27284005 0.31284005 0.35450671
[11] 0.39798498 0.44343952 0.49105857 0.54105857 0.59369015 0.64924570 0.70806923
0.77056923 0.83723590 0.90866447
[21] 0.98558755 1.06892088 1.15982997 1.25982997 1.37094108 1.49594108 1.63879823
1.80546489 2.00546489 2.25546489
[31] 2.58879823 3.08879823 4.08879823

$time
 [1] 41.953 47.205 47.774 49.035 50.394 50.760 52.675 53.459 55.999 56.530 57.245 57.554
58.575 59.102 60.567 60.897
[17] 62.449 63.440 63.530 63.615 63.648 63.797 64.678 69.067 69.620 70.113 70.953 73.696
73.832 74.369 76.276 84.344
[33] 93.423

>
survdiff(Surv(PerfectionFlash_data_8_$timeUsed)~PerfectionFlash_data_8_$matchingScheme,
data = PerfectionFlash_data_8_, rho = 0)
Call:
survdiff(formula = Surv(PerfectionFlash_data_8_$timeUsed) ~
PerfectionFlash_data_8_$matchingScheme,
    data = PerfectionFlash_data_8_, rho = 0)

                                                N Observed Expected (O-E)^2/E (O-E)^2/V
PerfectionFlash_data_8_$matchingScheme=diffColor 33       33     40.4      1.34      4.34
PerfectionFlash_data_8_$matchingScheme=shape     27       27     19.6      2.75      4.34

 Chisq= 4.3  on 1 degrees of freedom, p= 0.0372
```

```
>
survdiff(Surv(PerfectionFlash_data_8_$timeUsed)~PerfectionFlash_data_8_$matchingScheme,
data = PerfectionFlash_data_8_, rho = 1)
Call:
survdiff(formula = Surv(PerfectionFlash_data_8_$timeUsed) ~
PerfectionFlash_data_8_$matchingScheme,
    data = PerfectionFlash_data_8_, rho = 1)

                                              N Observed Expected (O-E)^2/E (O-E)^2/V
PerfectionFlash_data_8_$matchingScheme=diffColor 33     14.7     18.8      0.90      3.47
PerfectionFlash_data_8_$matchingScheme=shape     27     15.8     11.7      1.45      3.47

 Chisq= 3.5  on 1 degrees of freedom, p= 0.0626
```

Works Cited

[1] J. Stroop, "Studies of Interference in Serial Verbal Reactions," Journal of Experimental Psychology, 12 (1935): 643–662.