Serifs and their influence on font legibility: Mean legibility distances for 10 participants

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Abstract

Serifs have been attached to alphabet letters since Roman times. As of late, their effect on reading legibility has become a source of contention. The purpose of this study was to find which was more legible, words in serif font or words in sans serif font. Legibility was defined as the distance at which a printed word was just clearly recognizable. Two fonts of a similar stroke width were compared, one font sans serif (Arial Unicode MS) and the other with serifs (Georgia), in 10 participants. These fonts were compared in two visual acuity conditions, 20/20 (normal vision) and 20/40 (low vision). There was a significant difference in legibility, with the sans serif font being found to be more legible.

KEY WORDS: serif, sans serif, font, legibility, distance threshold, visual acuity, normal vision, low vision

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Introduction

According to Gomez-Palacia & Viti's (2009) *Graphic Design, Referenced: A Visual Guide to Language, Applications, and History of Graphic Design*, serifs are the finishing strokes found in roman typefaces for all letters, save O and Q. These strokes may be unilateral, such as the stroke found at the top of the letter "F" or bilataeral, such as the serif found at the bottom of the letter "F." Fonts with serifs originate from Roman inscriptional texts, such as the Trajan Column, which date back as early as the first century. There is debate as to how the serif came to be. They may have come about from characters being chiseled into stone, or also may have been painted onto the stone before characters were chiseled out (Gomez-Palacia & Viti, 2009).

There are conflicting reports on the effect serifs have on reading and legibility, as well as many different definitions of "legibility." It was found by a study where 40 older participants manipulated font characteristics that serifs modestly enhanced legibility as measured by the minimum size of print that could be read (Arditi, 2004). The individualized fonts produced rivaled Times New Roman in terms of legibility. In a similar study, individual letters were manipulated to decrease the chance of confusing letters for one another (Mackeben, 2000). Serifs, when added to a letter in frequently confused letter pairs (such as the D in the D-O pairing), aided legibility as letter recognition by making the letters appear less similar. It was found in a comparison of Courier (serif) and Arial (sans serif) font in people with age-related macular degeneration that the serif font allowed participants higher reading acuity (Tarita-Nistor, Lam, Brent, Steinbach, & Gonzales, 2013). Preferences for serifs, and this preference's effect on legibility has also been studied. Uysal & Duger (2012) tested writing and reading training effects on the preference of font size and type for 35 children from a primary school for the blind. In this

study, children preferred the serif font due to more distinct letter and word shapes they produced. Despite this preference, legibility was not enhanced.

Sans serif font first appeared in mid-19th century woodcarvings, and has been described as the "typographic equivalent of circumcision" (Gomze-Palacia & Viti, 2009). Several studies have found that sans serif fonts are more legible than their serif counterpart. Noting that past research in the serif-sans serif debate used fonts differing in more aspects than the presence or absence of serifs, Moret-Tatay & Perea (2011) compared the effects on word recognition had by two fonts of the Lucida family in twenty students from the University of Valencia during a word-nonword discrimination task. These fonts were Lucida Bright (serif font) and Lucida Sans (sans serif font) and differed only in the presence or absence of serifs. There was no benefit found to using serif font, and the researchers went as far as calling serifs a "decorative burden" while suggesting that serifs may be dropped from letters indefinitely over time.

Similar findings have also been found in other languages. A small but insignificant enhancement in legibility, as determined by reading speed, was found for sans serif font in 238 Russian medical students reading Cyrillic font (Akhmadeeva, Tukhvatulin, & Veytsman, 2012). In a study comparing Dutch (serif font) and Swiss (sans serif) fonts, serifs impeded reading speed near the acuity limit where serifs and thin strokes were theorized to disappear (Yager, Aquilante, & Plass, 1998). Arditi & Cho (2005) reported that serifs hindered legibility near the acuity limit, while having no effect on legibility as measured by reading speed.

There are studies that fall in the middle of this debate, claiming that serifs have no effect on legibility in its myriad definitions. When comparing serif and sans serif font, Perea (2013) found that there was no significant difference between the fonts, saying that there was "no theoretical

use of serifs beyond subjective preferences." Considering that past studies were conflicted on a whole as to the effect serifs had on legibility, Times and Helvetica fonts were compared by De Lange, Esterhuizen, & Beatty (1993) to test the hypothesis that serif and sans serif font were equally legible across different definitions of legibility, including reading speed and comprehension. It was found that there was no significant effect on legibility, and proposed that other factors play a larger role than serifs in legibility, such as becoming accustomed to a particular font (De Lange et al., 1993). Feely, Rubin, Ekstrom, & Perera (2005) compared different typefaces and sizes in order to determine whether or not serifs had an effect on reading fluency as determined by reading speed. In accordance with De Lange et al.(1993), the researchers found that serifs had no significant effect on reading fluency once fonts were controlled for size (Feely et al., 2005). Instead, size was found to have a significant effect on reading fluency. In terms of legibility as reading speed, Soleiman & Mohammadi (2012) found that serifs produced no difference in English not as First Language students.

Other factors than the presence or absence of serifs may affect the legibility of type, such as color, contrast, size of font, spaces between letters, letter case, and expectancy. While investigating the effects of color on legibility, Tinker & Patason (1931) found that black on white was the most legible of color combinations. Conversely, Legge, & Rubin (1986) found that color had no effect on legibility for people with normal vision. According to Saito, Saito, & Saito (2010), positive contrast (dark characters on a bright background) has proven most beneficial to young people without visual impairments. People with normal vision have also been found to be "remarkably tolerant" to changes made in contrast or character size (Legge, Rubin, & Luebker, 1987). This is supportive of finding that low vision is more susceptible to font differences, such as whether or not a font is fixed or proportionately spaced (Mansfield, Legge & Bane, 1996).

Letter case may also effect legibility, with evidence supporting uppercase being more legible (Arditi & Cho, 2007), as well as other sources alleging lowercase is more legible (Tinker, 1963, ch. 3).

The purpose of this study is to find which is more legible to readers, words displayed in serif font, or words displayed in sans serif font. This study uses a definition of legibility as determined by distance. Such a definition is advantageous to legibility defined by reading speed, because it allows for color information and fine detail to contribute to the recognition of letters and words. This contribution is less apparent in tests using reading speed as the slow conduction rate of the neurons conveying detail and colour information is compromised in such measurements. A distance definition of legibility is also compatible with the definition of visual acuity in humans using the 20/20 system (Nilsson, 2006).

Methods

A method of limits was used to distinguish distance thresholds. According to Nilsson (2006), the legibility distance threshold is "the distance at which a printed message or picture is just clearly recognizable," and is compatible with visual acuity as measured by a Snellen chart. At a greater distance threshold, a target (in the case of this particular study, a word) has a smaller retinal image, so to be read at such a distance indicates a higher legibility or visual effectiveness (Nilsson, 2001). This is useful for signage as it allows for earlier identification of important information, such as speed limits, locations, or distances.

Participants

Participants were 10 students, six male and four female, attending classes at the University of Prince Edward Island, whose visual acuity and color vision were assessed using a Snellen chart

and the Dvorine test, respectively. Participants were required to have 20/20 vision as well as normal color vision in order to take part in the study. Students were recruited through speaking with classes, fliers, and word of mouth. An incentive of $20 was used as part of the recruitment process. An information letter detailing the experiment was given to the participants to read before signing a consent form. The purpose of the experiment was explained by the observer, and serifs were described in case the participant had not known what a serif was. Participants were informed they could end their participation at any time.

Apparatus & Materials

Participants were made half of their measurements in each of two visual conditions: 20/20 (normal vision) and 20/40 achieved through the use of defocusing lenses. In each condition, six words were displayed from one of two word lists, alternating between Arial Unicode MS (sans serif) and Georgia (serif font), beginning with the sans serif font. Each word appeared twice, once in Arial Unicode MS and once in Georgia. Three males and two females were assigned to each list. Fonts used can be viewed in Figure 1. Word sets 3 and 4, in presentation order, can be seen in Figure 2. Word sets 1 and 2 were not used in this study, as they were used in a companion study (Speelman, 2014).

ARIAL UNICODE MS	ABCDEFGHIJKLMNOPQRSTUVWXYZ
GEORGIA	ABCDEFGHIJKLMNOPQRSTUVWXYZ

Figure 1: Fonts Used

Word Set 3	Word Set 4
DESIRE	TACKLE
IMAGED	WINTER
BEYOND	REVIVE
REASON	SQUARE
SPIRIT	COUNTY

MOTION	DEPART
IMAGED	WINTER
SPIRIT	COUNTY
REASON	SQUARE
DESIRE	TACKLE
MOTION	DEPART
BEYOND	REVIVE

Figure 2: Presentation Order of Words (this study)

Words were arranged to produce different sounds and letter combinations, and were chosen from the list studied and compiled by Benjafield & Muckenheim (1989). They were selected for a length of six letters and a familiarity ranking of 6.00 or higher, as rated by participants in that particular study (Benjafield & Muckenheim, 1989). Words were required to have this familiarity ranking to limit the possibility of participants having not seen the word before their participation in the study. The display showed black words on a white background. This display method (black on white or positive contrast) is supported by past work to be most legible (Saito et al., 2010; Tinker, 1931).

Word sets were put into slide shows created using Microsoft Power Point 2007, and were displayed using Adobe Reader. All words were presented in upper case letters, as capital letters have been found by past research to be more legible than lower case letters to those with poor acuity, such as participants in our 20/40 condition, and to people with normal vision if the letters are small enough (Arditi & Cho, 2007). Words were displayed in 36 point size, with a magnification of 75%, and were centred on the screen. At the closest viewing condition of 42cm (where the box is zeroed, waiting for the participant to start), the height of the letters on screen is 1 cm. This corresponded to a visual angle of 1.36 degrees. Calculations for visual angle can be seen in Figure 3.

tanVA = h/d

where

VA = visual angle h = height on screen d = distance between participant and stimulus

VA=arctan(h/d)

= arctan (1cm/42cm) = 1.36392 degrees

Figure 3: Calculation of Visual Angle

In a long, completely dark, black room, a carriage rode an 8m test track on linear bearings. A computer-controlled stepping motor controlled the speed of the carriage, and carriage positions were continuously monitored by an independent optical encoder and electronic register.

Procedure

After becoming familiar with the test procedure by practicing with three serif and three sans serif words in each vision condition, participants were tested individually, seated at one end of the track. The carriage started close to the participant and moved away until the participant found the letters beginning to blur. Upon blurring, the participant pressed a button for the computer to take a measurement, and the cart travelled a random distance away before returning. As the cart moved towards them, the participant would press a button indicating the letters had just become clear again. Measurements were taken in five pairs of back and forth pairs, repeated four times; half at 20/20 and half at 20/40.

Participants were asked to read each word aloud so an observer in an adjacent room, separated by a black curtain, could confirm the correct word was displayed. Using a track ball, participants would scroll to the next word once the measurements of a word were completed. Trials typically lasted between 90 minutes and two hours. Upon completion of their trials, participants were debriefed, given a debriefing letter, and given the opportunity to ask any questions they had.

Results

20/20 Visual Condition

For each word of the twelve words in the assigned word sets, ten readings of the cart moving away and returning towards the participant were taken. Of these ten readings, eight were used to create an average distance for every word displayed to participants. Table 1 holds the results of the 2-tailed t-test performed in Microsoft Excel comparing sans serif to serif font in each of the visual conditions. Average distances for Arial Unicode MS is displayed in Table 2 and average distances for Georgia are displayed in Table 3, found in the Appendix of this paper.

Table 1: *t*-test results comparing sans serif and serif font legibility

Paired Samples Test						
	Mean	**SD**	**SE**	*t*	*df*	**Significance (2-tailed)**
Sans Serif -Serif 20/20	11.961	13.295	4.431	2.699	9	2.262
Sans Serif -Serif 20/40	11.437	11.085	3.7	3.095	9	2.821

On average, participants during the 20/20 condition found Arial Unicode MS, the sans serif font, significantly more legible than Georgia, the serif font, $t(9) = 2.699$, $p < .05$. In the 20/20 condition, participants experienced a reduction of 5.17% in relative legibility when viewing words displayed in Georgia font as opposed to Arial Unicode MS. Calculations for relative legibility can be found in Table 7 in the Appendix of this paper.

20/40 Visual Condition

Each of the participants repeated the procedure done for the 20/20 condition while wearing defocusing lenses that reduced their visual acuity to 20/40. Average distances found for Arial Unicode MS are displayed in Table 3 and Table 5 holds the average distances found for Georgia

in the 20/40 condition. Both Tables can be viewed in the Appendix section. The results of a *t*-test done in order to compare the averages of these two fonts can be seen in Table 1.

On average, participants during the 20/40 condition found Arial Unicode MS, the sans serif font, significantly more legible than Georgia, the serif font, $t(9) = 3.095$, $p < .02$. In the 20/40 condition, participants experienced a reduction of 6.7% in relative legibility while viewing words displayed in Georgia font. Calculations for relative legibility can be seen in Table 7 in the Appendix section of this paper

Discussion

A companion study found there was no significant difference between Arial Unicode MS and Georgia font as measured by a distance threshold in ten participants (Speelman, 2014). However, when results of both tests are combined, there is a significant difference in both 20/20 and 20/40 conditions, suggesting that sans serif font is more legible than serif font as measured here. On average, participants during the 20/20 condition found Arial Unicode MS, the sans serif font, significantly more legible than Georgia, the serif font, $t(19) = 2.533$, $p < .05$, as did participants when undergoing the 20/40 condition, $t(19) = 3.260$, $p < .01$. Tables 8 and 9 of the Appendix display the average distances of legibility and the means for 20/20 and 20/40 conditions, respectively, from Speelman (2014), and a *t*-test table using data from both studies can be seen in Table 11 found in the Appendix.

In both the 20/20 condition and the 20/40 condition, participants found words displayed in Arial Unicode MS (sans serif) significantly more legible than those same words displayed in Georgia (serif). These fonts had a similar stroke width and their major difference was the presence or absence of serifs. These findings support past studies that say sans serif font are, in some way,

more legible than serif font (Akhmadeeva, et al., 2012; Arditi & Cho, 2005; Moret-Tatay & Perea, 2011; Yager et al, 1998). Words displayed in Georgia font had a shorter distance where they were legible, which could be explained by the idea that, near the acuity limit, serifs hinder legibility or disappear, rendering text unreadable (Arditi & Cho, 2005; Yager et al., 1998).

One strength of this study is that the fonts used were chosen in an attempt to control stroke width, letter size, and letter spacing. This is in contrast to several other studies where the fonts compared were not similar in most respects. Some researchers have attempted to mitigate this problem by using fonts of the same family, such as Lucida (Moret-Tatay & Perea, 2011; Pera, 2013). One of these studies found serifs provided no benefit to legibility, going so far as to refer to them as a "decorative burden" (Moret-Tatay & Perea, 2011). The other study found no significant difference (Perea, 2013). Another study found that, while there was a slight advantage over serif font, sans serif font was not significantly more legible (Akhmadeeva, et al., 2012). For future studies it is recommended that fonts used be differing only in terms of the presence or absence of serifs.

Another strength of this study is the limitation of how participant expectancy could influence the legibility of the fonts used. This was limited through the selecting of words which would be familiar for participants, and the same words and procedure being used for both visual conditions. Past research by Nilsson & Kaiserman (2004) has found that expectancy of participants, when it comes to words being read, is not a strong factor.

In this current study, where the words were moving, findings are more applicable to real world instances such as road signs than they are daily reading. While this study found a significant difference between the legibility of sans serif font and serif font, it should also be noted that

these words were displayed one at a time. Because of this, relating these findings to something involving continuous reading, such as reading a magazine, book, or webpage, would pose a problem. However, these findings could easily be applied to instances where signage is being viewed or created, as few words are used in order to communicate information held on signs.

The greater reduction in legibility seen in participants while wearing defocusing lenses that reduced their visual acuity to 20/40 seems to suggest that sans serif font would be more legible to people who have lost some vision due to ageing. Past research has shown that those with low vision, such as participants while undergoing the 20/40 condition are more affected by font differences than those with normal vision (Mansfield et al., 1996). However, in this study, both sets of visual conditions demonstrated a greater legibility when reading words displayed in sans serif font.

Conclusion

In both 20/20 and 20/40 visual conditions, on average, single words displayed in sans serif (Arial Unicode MS) font were found to be significantly more legible than serif font (Georgia). This supports past research that shows serifs are detrimental to legibility. Fonts were chosen for this study because of their similarity in many respects, save for the presence or absence of serifs. Despite this, there may be some differences. It is recommended for future studies that the fonts use only differ in respect to the presence or absence of serifs. Another potential problem is that neither of these fonts are commonly used, and for future studies, it is also recommended fonts used for study be something seen more often, such as Times New Roman.

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Appendices

Appendix A – Tables of Average Distance

Table 2: Average Distance of Legibility for Sans Serif Words in 20/20 Condition

SANS SERIF										
	Word Set 3					Word Set 4				
	Participants					Participants				
Word No.	**3**	**7**	**11**	**15**	**19**	**4**	**8**	**12**	**16**	**20**
1	588.74	398.43	397.13	340.34	339.67	528.54	557.87	423.29	352.47	400.22
3	576.18	357.66	490.01	368.78	454.77	560.05	613.23	448.59	444.96	414.47
5	594.22	365.54	395.63	271.83	366.09	588.29	601.59	455.36	473.47	404.98
7	597.28	327.81	428.04	342.76	362.06	578.78	562.03	464.93	369.36	406.9
9	643.59	361.7	445.44	407.71	421.66	635.28	614.83	455.07	423.59	376.34
11	630.52	389.04	407.9	332.72	348.38	644.15	593.62	423.37	445.29	390.68
Means:	605.09	366.70	427.36	344.02	382.11	589.18	590.53	445.10	418.19	398.93

Table 3: Average Distance of Legibility for Serif Words in 20/20 Condition

SERIF										
	Word Set 3					Word Set 4				
	Participants					Participants				
Word No.	**3**	**7**	**11**	**15**	**19**	**4**	**8**	**12**	**16**	**20**
2	581.31	370.04	449.22	403.92	374.58	527.58	525.74	426.64	375.68	403.62
4	558.78	340.26	415.38	358.16	353.5	526.42	506.21	441.4	481.1	379.02
6	579.52	368.81	419.09	379.57	377.68	601.19	556.68	436.93	416.69	385.07
8	621.07	328.59	381.52	247.77	376.4	588.55	560.02	422.07	440.13	361.97
10	639.87	357.61	378.67	331.72	348.97	592.45	592.5	431.18	425.82	371.53
12	604.79	375.42	416.19	323.7	433.79	623.23	552.38	436.85	443.97	357
Means:	597.56	356.79	410.01	340.81	377.49	576.57	548.92	432.51	430.57	376.37

Table 4: Average Distance of Legibility for Sans Serif Words in 20/40 Condition

SANS SERIF										
	Word Set 3					Word Set 4				
	Participants					Participants				
Word No.	**3**	**7**	**11**	**15**	**19**	**4**	**8**	**12**	**16**	**20**
13	402.52	281.27	335.83	258.18	203.32	566.38	503.07	253.31	201.21	147.4
15	436.57	285.24	382	268.64	212.83	630.26	559.35	278.83	248.68	143.17

17	486.55	282.51	270.89	247.36	193.82	628.1	573.06	280.89	188.17	143.69
19	488.94	282.81	298.66	271	200.23	602.59	549.06	282.67	194.18	164.87
21	545.89	283.35	343.92	282.05	205.55	595.31	525.12	273.23	197.42	155.97
23	526.23	273.92	374.31	265.14	214.49	613.73	577.75	263.47	241.44	142.73
Means:	481.12	281.52	334.27	265.40	205.04	606.06	547.90	272.07	211.85	149.64

Table 5: Average Distance of Legibility for Serif Words in 20/40 Condition

SERIF										
	Word Set 3					**Word Set 4**				
	Participants					**Participants**				
Word No.	**3**	**7**	**11**	**15**	**19**	**4**	**8**	**12**	**16**	**20**
14	419.86	274.83	350.69	236.28	199.56	555.73	555.48	250.22	240.34	151.07
16	456.45	290.74	287.68	246.94	204.34	629.74	508	268.9	218.51	144.94
18	471.85	277.7	291.59	254.12	205.41	591.21	539.86	274.57	225.02	143.22
20	507.08	277.96	272.96	222.99	201.87	559.38	525.03	261.89	182.76	146.6
22	505.83	278.75	311.52	253.09	208.51	545.34	544.74	242.19	228.85	130.73
24	510.86	288.32	334.97	221.48	183.07	592.85	527.13	268.16	205.91	137.26
Means:	478.66	281.38	308.24	239.15	200.46	579.04	533.37	260.99	216.90	142.30

Appendix B – Mean and *t*-value Calculations

Table 6: Mean and *t*-value calculations

AVG Distance										
20/20	**Word Set 3**					**Word Set 4**				
Sans Serif	**3**	**7**	**11**	**15**	**19**	**4**	**8**	**12**	**16**	**20**
1	588.74	398.43	397.13	340.34	339.67	528.54	557.87	423.29	352.47	400.22
3	576.18	357.66	490.01	368.78	454.77	560.05	613.23	448.59	444.96	414.47
5	594.22	365.54	395.63	271.83	366.09	588.29	601.59	455.36	473.47	404.98
7	597.28	327.81	428.04	342.76	362.06	578.78	562.03	464.93	369.36	406.9
9	643.59	361.7	445.44	407.71	421.66	635.28	614.83	455.07	423.59	376.34
11	630.52	389.04	407.9	332.72	348.38	644.15	593.62	423.37	445.29	390.68
MEANS	605.0883	366.6967	427.3583	344.0233	382.105	589.1817	590.5283	445.1017	418.19	398.9317
Serif										
2	581.31	370.04	449.22	403.92	374.58	527.58	525.74	426.64	375.68	403.62
4	558.78	340.26	415.38	358.16	353.5	526.42	506.21	441.4	481.1	379.02
6	579.52	368.81	419.09	379.57	377.68	601.19	556.68	436.93	416.69	385.07
8	621.07	328.59	381.52	247.77	376.4	588.55	560.02	422.07	440.13	361.97
10	639.87	357.61	378.67	331.72	348.97	592.45	592.5	431.18	425.82	371.53
12	604.79	375.42	416.19	323.7	433.79	623.23	552.38	436.85	443.97	357
MEANS	597.5567	356.7883	410.0117	340.8067	377.4867	576.57	548.9217	432.5117	430.565	376.3683
DIFF of Means	7.531667	9.908333	17.34667	3.216667	4.618333	12.61167	41.60667	12.59	-12.375	22.56333
									Mean Dif:	11.96183
									SD of Dif:	13.29493
									SE of Dif:	4.431642
									***t*-value:**	2.699187
20/40										

Sans Serif										
13	402.52	281.27	335.83	258.18	203.32	566.38	503.07	253.31	201.21	147.4
15	436.57	285.24	382	268.64	212.83	630.26	559.35	278.83	248.68	143.17
17	486.55	282.51	270.89	247.36	193.82	628.1	573.06	280.89	188.17	143.69
19	488.94	282.81	298.66	271	200.23	602.59	549.06	282.67	194.18	164.87
21	545.89	283.35	343.92	282.05	205.55	595.31	525.12	273.23	197.42	155.97
23	526.23	273.92	374.31	265.14	214.49	613.73	577.75	263.47	241.44	142.73
	481.1167	281.5167	334.2683	265.395	205.04	606.0617	547.9017	272.0667	211.85	149.6383
Serif										
14	419.86	274.83	350.69	236.28	199.56	555.73	555.48	250.22	240.34	151.07
16	456.45	290.74	287.68	246.94	204.34	629.74	508	268.9	218.51	144.94
18	471.85	277.7	291.59	254.12	205.41	591.21	539.86	274.57	225.02	143.22
20	507.08	277.96	272.96	222.99	201.87	559.38	525.03	261.89	182.76	146.6
22	505.83	278.75	311.52	253.09	208.51	545.34	544.74	242.19	228.85	130.73
24	510.86	288.32	334.97	221.48	183.07	592.85	527.13	268.16	205.91	137.26
MEANS	478.655	281.3833	308.235	239.15	200.46	579.0417	533.3733	260.9883	216.8983	142.3033
Diff of MEANS	2.461667	0.133333	26.03333	26.245	4.58	27.02	14.52833	11.07833	-5.04833	7.335
									Mean Dif:	11.43667
									SD of Dif:	11.08506
									SE of Dif:	3.69502
									***t*-value:**	3.095157

Appendix C – Relative Legibility

Relative legibility is used to compare the legibility between the two fonts used. Since the sans serif (Arial Unicode MS) was found to be more legible than the serif font (Georgia), it was allowed to equal 1 in these calculations. Doing it this way revealed a percentage decrease in legibility when using Georgia, as opposed to Arial font.

Table 7: Relative Legibility and its calculation

20/20				**20/40**			
Mean Sans Serif	456.7205			**Mean Sans Serif**	335.4855		
Distance Squared	208593.6151			**Distance Squared**	112550.5		
This legibility = 1				**This legibility=1**			
Mean Serif	444.7586667			**Mean Serif**	324.0488		
Distance Squared	197810.2716			**Distance Squared**	105007.6		
Relative Legibility	0.948304537	5.169546		**Relative Legibility**	0.932982	6.701768	
when *df* = 9, *t*=2.699				**when *df* = 9, *t*=3.095**			
AVG Dif	**SD of Dif**		**SE of Dif**	**AVG Dif**	**SD of Dif**		**SE of Dif**
11.961	13.295		4.431	11.437	11.085		3.7
for significance, *t* ≥ 2.262 where p = .05				**for significance, *t* ≥ 2.821 where p = .02**			

Appendix D – Data from Speelman (2014)

Speelman (2014) was a companion study. There were an equal number of participants and the procedure, apparatus, and materials were the same. The only thing that differed was the word sets used. Speelman (2014) use word sets that we labelled "Word Set 1" and "Word Set 2" while this study used word sets labelled "Word Set 3" and "Word Set 4."

Table 8: Average Distance of Legibility & Means for 20/20 Condition (Speelman, 2014)

20/20										
SANS SERIF										
	Word Set 1					**Word Set 2**				
	Participants					**Participants**				
Word No.	**1**	**5**	**9**	**13**	**17**	**2**	**6**	**10**	**14**	**18**
1	285.81	273.3	201.28	374.39	561.67	404.05	414.38	359.91	327.26	484.28
3	314.56	265.47	222.14	346.65	586.37	411	406.36	330.29	329.77	506.94
5	326.59	222.14	256.09	325.32	595.25	412.72	514.45	298.5	298.34	509.28
7	422.24	226.61	225.65	376.2	630.37	401.51	439.91	282.99	310.14	518.05
9	375.97	183.4	243.19	366.61	631.27	404.29	465.28	286.38	277.99	562.87
11	400.18	293.04	252.86	376.18	638.75	400.28	539.22	244.11	319.48	539.55
Means:	354.225	243.9933	233.535	360.8917	607.28	405.6417	463.2667	300.3633	310.4967	520.1617
SERIF										
	Word Set 1					**Word Set 2**				
	Participants					**Participants**				
Word No.	**1**	**5**	**9**	**13**	**17**	**2**	**6**	**10**	**14**	**18**
2	330.63	231.66	213.51	361.78	612.21	412.89	346.46	272.99	315.1	468.73
4	296.94	223.41	231.37	351.95	627.77	411.46	458.14	306.66	366.53	452.65
6	361.61	215.68	274.71	340.55	567.99	400.71	464.07	268.78	324.11	539.94

8	354.07	209.56	195.27	333.26	571.74	400.56	309.76	305.37	301.6	602.11
10	388.5	164.9	242.83	358.09	529.75	398.17	313.95	274.94	328.09	546.18
12	400.08	256.98	250.11	371.41	587.69	398.63	422.51	282.01	313.55	618.18
Means:	355.305	217.0317	234.6333	352.84	582.8583	403.7367	385.815	285.125	324.83	537.965
Diff of Means:	-1.08	26.96167	-1.09833	8.051667	24.42167	1.905	77.45167	15.23833	-14.3333	-17.8033

Table 9: Average Distance of Legibility & Means (Speelman, 2014)

20/40										
SANS SERIF										
	Word Set 1					**Word Set 2**				
	Participants					**Participants**				
Word No.	**1**	**5**	**9**	**13**	**17**	**2**	**6**	**10**	**14**	**18**
13	200.84	136.18	209.02	412.99	511.81	240.82	288.47	290.88	231.92	529.28
15	214.53	143.79	213.09	358.39	479.35	159.17	307.75	274.03	244.75	540.05
17	215.31	149.1	247.03	340.34	521.5	184.68	288.41	250.59	306.69	455.49
19	192.02	131.01	209	394.13	582.56	203.84	208.76	251.74	311.93	337.71
21	234.39	148.96	224.06	393.46	564.35	179.76	178.49	226.39	326.78	427.13
23	260.43	142.53	217.06	401.71	613.11	192.2	136.99	277.46	400.09	458.09
Means:	219.5867	141.9283	219.8767	383.5033	545.4467	193.4117	234.8117	261.8483	303.6933	457.9583
SERIF										
	Word Set 1					**Word Set 2**				
	Participants					**Participants**				
Word No.	**1**	**5**	**9**	**13**	**17**	**2**	**6**	**10**	**14**	**18**
14	205.46	142.03	200.86	411.94	525.23	180.01	261.51	252.85	215.85	457.09
16	236.55	137.02	200.18	360.8	470.37	164.11	261.25	303.5	278.12	467.28
18	242.59	136.13	246.6	383.4	519.04	171.67	248.97	206.19	302.15	482.03
20	213.84	132.86	236.68	349.22	513	169.84	212.07	197.14	285.01	454.75
22	248.18	140.95	202.39	349.83	481.82	159.81	151.13	258.79	313.55	503.07

24	242.24	150.68	260.65	378.4	564.58	161.15	126.32	280.23	294.42	493.59
Means:	231.4767	139.945	224.56	372.265	512.34	167.765	210.2083	249.7833	281.5167	476.3017
Diff of Means:	-11.89	1.983333	-4.68333	11.23833	33.10667	25.64667	24.60333	12.065	22.17667	-18.3433

Appendix E – Tables incorporating data from Speelman (2014)

Table 10: Relative Legibility and its calculation incorporating data from Speelman (2014)

20/20			**20/40**		
Mean Sans Serif	418.353		**Mean Sans Serif**	315.846	
Distance Squared	175019.2		**Distance Squared**	99758.7	
This Legibility = 1			**This Legibility = 1**		
Mean Serif	406.3863		**Mean Serif**	305.3325	
Distance Squared	165149.9		**Distance Squared**	93227.94	
Relative Legibility	0.94361	5.639026	**Relative Legibility**	0.934534	6.546557
when *df* = 19, *t* = 2.533			**when *df* = 19, *t* = 3.26**		
AVG Dif	**SD of Dif**	**SE of Dif**	**AVG Dif**	**SD of Dif**	**SE of Dif**
11.967	20.593	4.724	10.514	14.058	3.225
for significance, *t* ≥ 2.262 where p = .05			**for significance, *t* ≥ 2.861 where p = .01**		

Table 11: *t*-test results incorporating data from Speelman (2014)

	Paired Samples Test					
	Mean	**SD**	**SE**	*t*	*df*	**Sig. (2-tailed)**
Sans Serif -Serif 20/20	11.967	20.593	4.724	2.533	19	2.093
Sans Serif -Serif 20/40	10.514	14.058	3.225	3.26	19	2.861

Appendix F – Consent Form

CONSENT FORM

Researcher: Chris Bailey

cbailey@upei.ca

Supervisor: Thomy Nilsson

nilsson@upei.ca

Introduction

You are invited to participate in a research project studying word/letter characteristics and their effect on readability. Chris Bailey will conduct the research supervised by Thomy Nilsson in the Department of Psychology at UPEI. We are conducting this study to fulfill the requirements of Psychology 490, Honours Thesis.

If you choose to take part in this project, it will take 80 minutes of your time, and you will not be harmed. You may stop participating at any time without consequence. You are assured total anonymity and any contact information obtained will be destroyed/deleted when the study is completed.

By participating in this project, you are given $20.

If you have any questions or concerns, you can contact Thomy Nilsson via his email, nilsson@upei.ca

The Research Ethics board of UPEI has approved this research project. If you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, or the ethical conduct of this study, you may contact the UPEI Research Ethics Board, for assistance at (902)566-0637, lmacphee@upei.ca

Purpose of the Study

The purpose of this study s to find the effects of serifs (the finishing strokes at the end of Roman letters), and text and background color combinations have on the legibility of words. This information could lead to more legible road signs or more effective advertising.

Study Design

In a dark room, you will be presented with a word on a monitor that is in a motorized cart residing on an 8m track. This cart will being close to you so you can read the word, and then move away. When you can no longer make out the word, you press a button. The cart then moves away from you before returning, and you press the button when you can read the word. You are expected to do this five times each way for each condition. Sometimes the words will have serifs, sometimes they will not. The colour of the text and background will occur in three blocks, black text on white background, white text on a green background, and pink text on a black background. You will complete these trials with your typical vision, and then be asked to use defocusing lenses to reduce you visual acuity (your typical vision will be 20/20, and defocused will be 20/40). This will take place in the Vision Research Lab in the basement of the Memorial building on UPEI campus.

Who Can Participate in the Study

You may participate in this study if you are a student at the University of Prince Edward Island, have normal or corrected-to-normal vision as confirmed by a Snellen Chart, and have regular colour vision as assessed by a Dvorine Test. There will an approximate total of 20 participants in this study.

Who Will Be Conducting the Research

The principal researcher of this study is Christopher Bailey, supervised by Thomy Nilsson of the Psychology Department of the University of Prince Edward Island.

What You Will Be Asked to Do

You will be asked to press a button indicating when a word becomes legible/illegible as it moves away/towards you along an 8m track. The words you will view will sometimes have serifs and sometimes will not, as well as have different text/background colours. Colour conditions will remain the same until 10 trials (five towards/five away) are completed and then will be switched. This will be done under normal viewing conditions before you will be asked to use defocusing lenses to limit your visual acuity to 20/40.

Possible Benefits

Data gathered by your participation may provide information that could lead to the creation of more legible road signs or more effective advertising.

Compensation

There is no cost to your participation in the study. For participating, you receive twenty dollars, Canadian.

Confidentiality and Anonymity

Your participation in this study will remain anonymous, and any contact information will be properly discarded when the study is complete.

Questions

If you have any questions, do not hesitate to contact Chris Bailey at cbailey@upei.ca

Problems or Concerns

If you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, or the ethical conduct of this study, you may contact the UPEI Research Ethics Board, for assistance at (902)566-0637, lmacphee@upei.ca

SERIFS AND THEIR INFLUENCE ON FONT LEGIBILITY

Please sign to indicate that you have and understood the information given, and that you give consent to participate in this study.

Participant name (printed): _____ x

Participant signature: _____ x

Date signed: _____ x

If you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, or the ethical conduct of this study, you may contact the UPEI Research Ethics Board, for assistance at (902)566-0637, lmacphee@upei.ca

Researcher name (printed): _____ x

Researcher signature: _____ x

Date signed: _____ x