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ORIGINAL ARTICLE

Readability, Subjective Preference and Mental Workload Studies on Young Indian Adults for Selection of Optimum Font Type and Size during Onscreen Reading

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Abstract: Font type and size characteristics play an important role in understanding the complexities of visual information in human-computer interface. India has emerged as the fastest growing personal computer (PC) user in the Asia pacific region. Studies and guidelines on the use of font type and size on screen for computer users are limited in the literature. Present work evaluates the influence of font type and size on reading on a computer screen in a group of young adults. Forty subjects volunteered for the study. Two types of fonts were used. Serif fonts included Times New Roman (TNR), Georgia and Courier New. Sans serif fonts included Arial, Verdana and Tahoma. These fonts were presented in 10, 12 and 14 point sizes. Subjects read eighteen passages (same length and reading level). Reading time, ranking and mental workload were measured. Readability was better for Serif compared to Sans serif. Reading time was minimum for Courier New 14 point. Sans serif fonts were preferred more than Serif fonts. Subjects' ranking was highest and mental workload was least for Verdana 14 point. The present study recommends using 14 point sized fonts for reading on computer screen. Courier New is recommended based on reading time while for making onscreen presentation more attractive, Verdana is recommended based on subjects' ranking and mental workload scoring.

Keywords: Serif fonts, Sans serif fonts, Reading, Ranking, Overall mental workload

Introduction

In recent years, reading a text from the computer screen has become an essential part in our daily life and as a result human-computer interactions are becoming more and more closely interrelated. We are experiencing a shifting of media: from the printed paper to the computer screen. This transition is modifying the process of how we read and understand a text. Research in human computer interfaces aims at a natural interaction between a user and an application system. Font type and size characteristics play an important role in understanding the complexities of visual information in human-computer interface. These issues are common for printed matter as well as digital media. There are certain rules of typography which are followed by the printing press that have limitations for application in the digital media. It has been well documented that different typefaces or fonts carry different connotations and have different influences on the readability, assimilation, interpretation and impact of the words and concepts they represent. Fonts themselves

have four major qualities, commonly referred to as the 'elements' of type. These are line, weight, orientation and size. Every font is created through the use of a distinctive mix of these four elements [1]. A fraction of a millimeter can be the difference between an aesthetically appealing and unappealing letter [2]. The most basic form of font type classification is simply into Serifs and Sans serifs. A Serif font is one in which lines or curves adorn the ends of each letter, such as Georgia. A Sans serif font is one which is without such adornment at the end of each letter, e.g. Arial.

The most common font types on computer screen are Times New Roman (TNR) and Georgia (Serif) and Arial and Verdana (Sans serif). TNR and Arial were originally developed for print and are the most common fonts of their respective font typeface used today. Times New Roman was designed for both legibility and economy of print space and became a popular font for print. Georgia and Verdana were developed specifically for use in the computer screen [3-4]. These font types were designed because of their increased legibility, having a relatively large x-height compared to Times New Roman. Tahoma and Courier New are also widely used font typeface in recent times. Font sizes are customarily described in points. Although historically points varied slightly from country to country, all points were approximately the same size. The modern, standardized system has exactly 12 points in a pica and exactly 6 picas in an inch. There are 72 points in one linear inch [5-6]. The size of a font refers to the maximum possible letter size. In general, for reading purpose 10, 12 and 14 point fonts are used. The effect of font type on readability from a computer screen was investigated by several investigators [3-4, 7-9]. Boyarski et al. [3] found no differences in the reading speed and comprehension among the three fonts except preference for Georgia over TNR. Increased legibility of Serif font than Sans serif font was observed from the study of Grant and Branch [7]. Opposite observations were reported by some researchers [9-13]. Subjects preferred Sans serif fonts more compared to Serif fonts in the studies of Boyarski et al. [3], Bernard et al. [14] and Tullis et al. [15].

The effect of font size on readability from a computer screen was investigated by a numerous researchers [8, 11, 16-18]. Mills and Weldon [16] reported that smaller size characters produced faster reading than larger characters. Geske [11] hypothesized that 14 point type would be more legible than 12 point type, which would in turn be faster than 10 point type. Bernard et al. [8] investigated how different font sizes affect actual and perceived readability for elementary level children. The children showed a preference for larger fonts. Bernard et al. [17] compared the readability and legibility of TNR (Serif) and Arial (Sans serif) fonts by studying readability with relation to typeface, size, and format on thirty five young volunteers. The researchers concluded that the most important factor in determining font preference was not Serif or Sans serif but instead font size. Their subjects preferred the larger 12 point font. Although these subjects indicated that they preferred Arial, there was no difference in terms of readability between Arial and TNR. From all these previously reported literature it is clear that the findings of these studies differ from each other and are limited to a fewer font types, sizes only.

According to a survey conducted by Confederation of Indian Industry [19], India has emerged as the fastest growing personal computer (PC) users in the Asia Pacific region and the average age of the home PC user is around 28 years. There is no specific font type and size till date designated as standard for use for reading on screen for computer users in the world. In view of the above, the study reported here comprises an investigation of the effect of various font type and size interface during reading on computer screen in young adults. The proposed study seeks to explore the impact of font type and size on reading behaviour on computer screen. In this study, readability of subjects in various font type and size interface was measured; subjects rated the perceptual qualities possessed by combination of different type faces and font sizes during reading on computer screen. The study also tried to compare overall mental workload experienced by subjects during reading of the texts in different font type and size combination. The observations of the present study will help us to decide the suitable font type and size combination for presentation of text on computer screen for young adults who are the major users of computer in India.

Materials and Methods

Participants: Forty (21 male and 19 female) young Indian subjects volunteered for this study. Their mean age (SEM) was 27.5 (0.31) yrs. All were tested to have 20/20 or better unaided or corrected vision as measured by a Snellen near acuity test for 20/20 vision at a distance of 18 inches. All of the participants reported to have regularly read documents on computer screen for varied lengths of time in 24 hr period. All participants read English fluently and all of them were postgraduates in science subjects. All the participants gave informed consent before the beginning of the experiment. Study protocol was approved by the Institute's ethics committee and this experiment conforms with the principles outlined by the Declaration of Helsinki protocol, 1964.

Apparatus:

1. A 17 inch TFT-LCD monitor with a 440 mm diagonal screen provided an active viewing area of 339 mm horizontally and 271 mm vertically. The screen resolution was 1280 by 1024 pixels. The screen images were refreshed at a rate of 60 Hz.
2. A digital stop watch (Racer).
3. A measuring tape for the measurement of viewing distance.

Workplace conditions: The TFT-LCD was positioned on a table 70 cm in height with an inclination angle of 105^{o} [20-21] with respect to the vertical axis. Participants were asked to sit at a comfortable distance from the computer as they normally practiced during routine computer work. An average distance of 65.7 $\pm$ 3.73 centimeters from the computer screen was found to be maintained by them during the experiment. The ambient illumination was maintained by fluorescent lamps and was about 450 lux. No glare appeared on the TFT-LCD screen. The computer operating system used was Microsoft's windows XP.

Font type and size combinations: Two types of fonts were used - the Serif fonts and the Sans serif fonts. Serif fonts included Times new Roman (TNR), Georgia and Courier New; Sans serif fonts included Arial, Verdana and Tahoma because of their frequent usage. All these fonts were presented in three different sizes, i.e. 10 point, 12 point and 14 point. Hence, a 6 x 3 (font type x size) within-subjects design matrix was used to investigate differences in preference for reading text. The different font typeface and size combinations are shown in Table 1.

Table-1: Different font type and size combinations

Serif fonts	Sans serif fonts
Times New Roman Georgia Courier New	Verdana Arial Tahoma
Times New Roman Georgia Courier New	Verdana Arial Tahoma
Times New Roman Georgia Courier New	Verdana Arial Tahoma

Task design: Font conditions were compared by having participants read eighteen passages. The text of each passage comprised of a font from one of the eighteen type and size font conditions. The passages came from Microsoft's electronic library, Encarta [22]. The passages were written at approximately the same reading level and discussed similar material (all dealt with religion - related topics). The passages were also adjusted to have approximately the same length (an average of 657 words per passage, SEM of 1.87 words). The number of words per line varied as a result of the width of the fonts within the different type and size combinations. The words used had almost the same level of difficulty. The colour of the font in all passages was black on a white background.

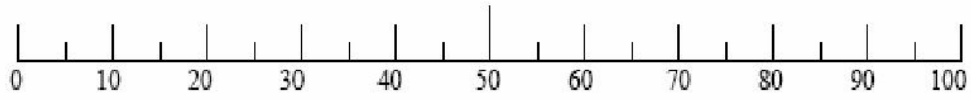
Procedure: During the experiment, participants were asked to read aloud one of the passages from the eighteen font type and size combinations as quickly and as accurately as possible. Subjects were allowed to take rest for about 10-15 minutes

between each trial. Some simple comprehension questions were given to the subjects after a certain percentage of experimental trials to ensure that participants read and fully understood the stimuli. Reading time was recorded by using a digital stop watch. Accuracy of reading (in terms of "omission" and "misreading") were noted during the time of reading by two experimenters. Beside this, entire reading period of each subject was audio recorded and analyzed later in order to score "omission" and "misreading" of each passages. Accuracy of about 80% was the consideration point for subject selection for further analysis. Immediately after reading all passages subjects ranked each font type and size combination for general preference on a seven-point scale (-3 = difficult to read, -2 = very poor, -1 = poor, 0 = average, 1 = good, 2 = very good, 3 = excellent).

The NASA-TLX [23] questionnaire was used to measure the overall mental workload. Although this method provides six dimensions, this experiment used only four dimensions, i.e., mental demand, performance, effort and frustration. The other two dimensions i.e. physical demand and temporal demand are not related to the reading task and therefore, were not included in the evaluation scale. Each of the four dimensions has a 100 point scale with an increment of 5 points starting from '0'. After reading each passage subjects were asked to rate the scale in response to the following questions related to each dimension of mental workload.

1) **Mental Demand**

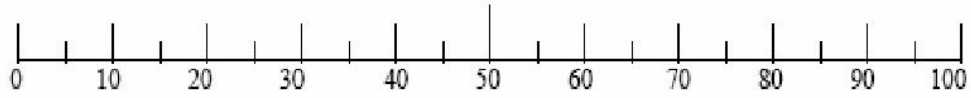
How much mental and perceptual activity was required?



Low High

2) **Performance**

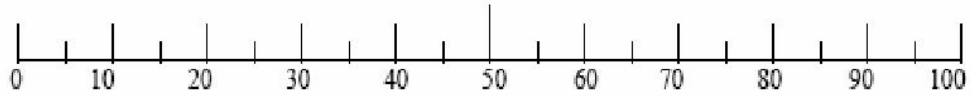
How satisfied were you with your reading performance?



Good Bad

3) **Effort**

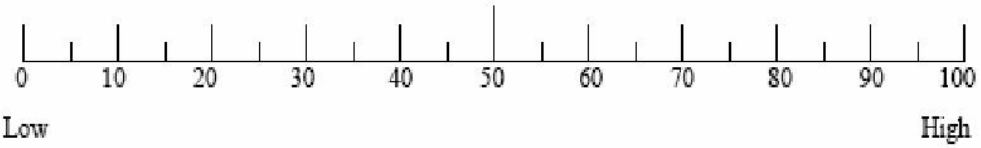
How hard did you have to work to accomplish your level of reading performance?



Low High

4) **Frustration**

How insecure, discouraged, irritated, and stressed versus secure, gratified, content, and relaxed did you feel during the reading task?



The weighted mean of the four dimensions of this questionnaire was used to evaluate the overall mental workload of each experimental condition.

Data analysis: Statistical analysis of the data on reading time was carried out by using two way analysis of variance (ANOVA) with repeated measures between different font types and font sizes. Interaction effects between font type and size on reading time were also analyzed. Student-Newman Keuls (SNK) post hoc test was used for pair wise comparison between different font types and sizes and changes were considered as significant when p values < 0.05 were reported.

The data for ranking of different font type and size combination as rated by participants and data for overall mental workload of different font type and size interface were analyzed by using Friedman's chi square (χ^2) test. Student-Newman Keuls (SNK) post hoc tests were used for these parameters for pair wise comparison between different font conditions and changes were considered as significant when p values < 0.05 were reported.

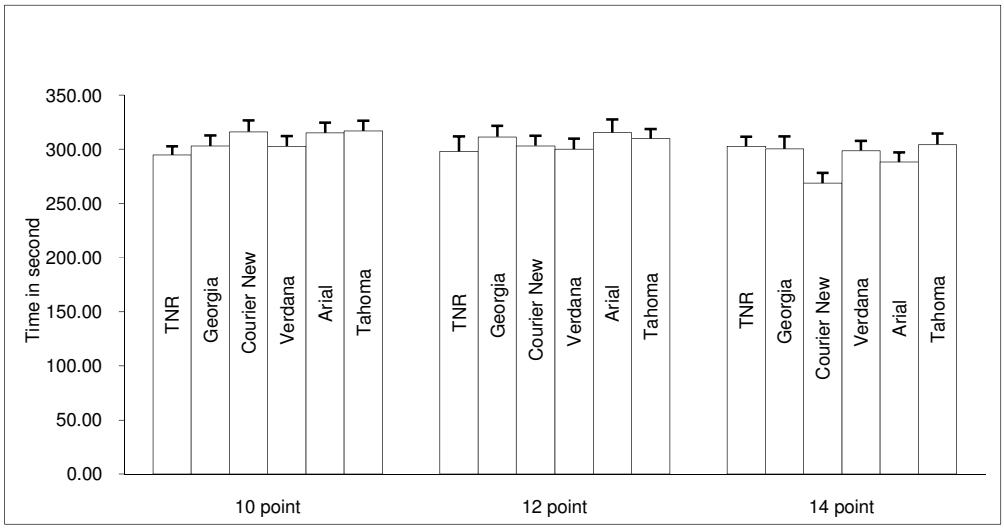
The data of reading time and overall mental workload for Serif and Sans serif fonts were analyzed separately, combining all three Serif fonts together and all three Sans serif fonts together of all the participants. Their average values were taken. Statistical comparison between Serif vs. Sans serif fonts have been performed by using paired Student's t test.

Results

Reading time:

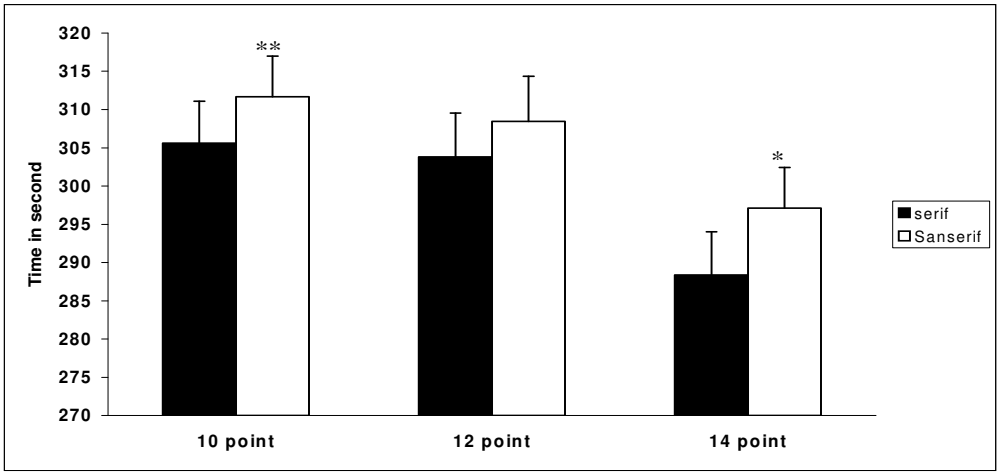
Figure 1 shows that average reading time was minimum for Courier New 14 point (268.88 ± 9.22 sec) and was significantly less ($p<0.01$) compared to any other font type and size combination (Fig. 1). It was followed by Arial 14 point font. No significant interaction was observed between different font types and sizes on this parameter.

Figure-1: Comparison of readability in time between different font type and size combinations



Serif font's average reading time was less than Sans serif fonts (Fig. 2) and the changes were significant for font size 10 point ($p<0.01$) and 14 point ($p<0.05$).

Figure-2: Comparison of readability in time between Serif and Sans serif fonts of different sizes

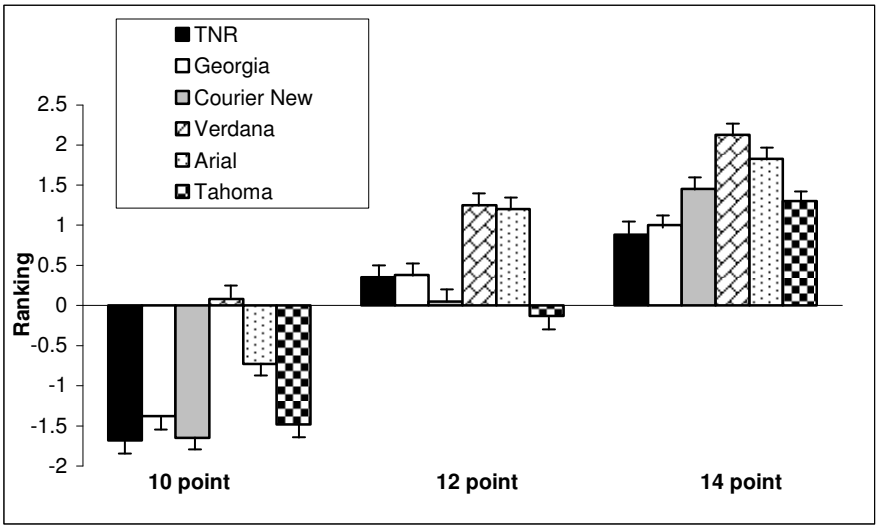


* = p < 0.05, ** = p < 0.01

Ranking of fonts:

Subjects ranked different font type and size combinations on a seven point scale. They ranked Verdana 14 point (2.13 ± 0.2) as the best font type and size combination in comparison to any ($p<0.01$) other font variation (Fig. 3). Arial 14 point (1.83 ± 0.15) was ranked as the second best. However, no significant change was observed between Verdana and Arial.

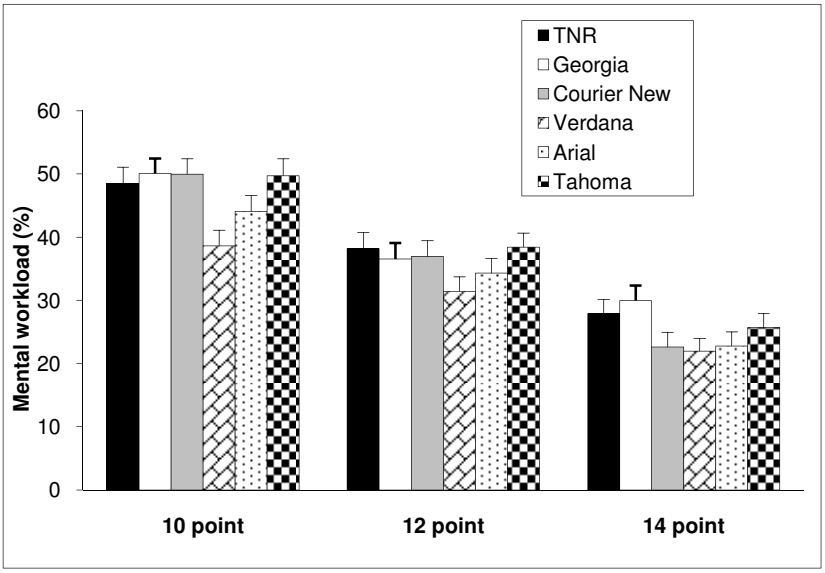
Figure-3: Ranking of different font type and size combinations



Overall mental workload:

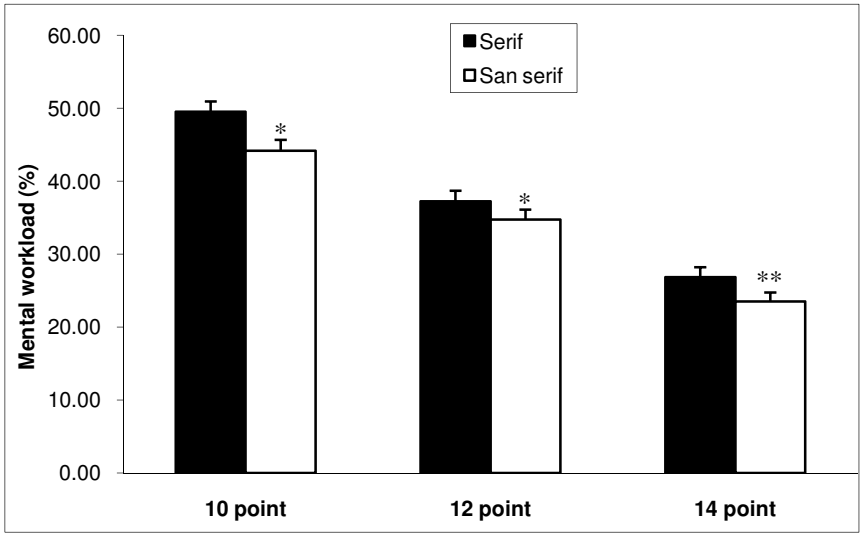
Overall mental workload for each font type and size combination and Serif and Sans serif fonts were calculated by averaging the four dimensions of NASA TLX with the same weight. It was least for Verdana 14 point font (21.97 $\pm$ 2.19), followed by Courier New 14 point (22.66 $\pm$ 2.32) and Arial 14 point (22.81 $\pm$ 2.00) fonts. No significant difference was observed between these three combinations (Fig.4).

Figure-4: Overall mental workload during reading of different font type and size combinations



Mental workload was significantly ($p<0.01$) least for reading 14 point Sans serif font compared to others (Fig.5).

Figure-5: Comparison of overall mental workload between Serif and Sans serif fonts in three different sizes



* = p < 0.05, ** = p < 0.01

Discussion

The main aim of the present study was to have an idea on the most suitable font type and size combination for presentation of text on computer screen during reading. Hence, the experiment was carried out on a particular age group population who are the major user of computer with almost equal merit level. The observations of the present study corroborate with the findings of some previously reported studies [4, 8, 17, 24] while differ from that of the others [3, 9-10].

It was observed that Serif font was more legible than Sans serif font in all three font sizes and it was also true for individual font e.g. reading time was less for TNR at 10 and 12 point size and least for Courier New at 14 point size. All of them belong to Serif family. This corroborates with the findings of Grant and Branch [7] who found a large, meaningful and statistically significant difference in means of reading time of different font types. They observed that, Serif faces were read faster than Sans serif. However, the present study differs from the findings of others [9-13] who found no significant differences for speed of reading with regard to font selection. There are some explanations about the increased readability of Serif fonts than Sans serif. According to De Lange et al. [25] serifs are used to guide the horizontal "flow" of the eyes; the lack of serifs is said to contribute to a vertical stress in Sans serifs, which is supposed to compete with the horizontal flow of reading. Serifs are used to increase contrast (and irregularity) between different letters to improve identification. Reynolds [26] showed that whole words written in Serif typefaces

can be recognized just as quickly as letters during an eye fixation and that single letters can be identified quicker when embedded in a word. Many studies conducted in the past did indeed find a preference for Serif typefaces and this perceived legibility was due to a great extent to familiarity with the typeface [27-28]. The present study offers evidence that readability as indicated by speed of reading is a delicate indicator of typeface and Serif font is better than Sans serif fonts.

Type size was found to play a role in speed of reading. The text presented at 14 point size was read faster than either 10 or 12 point type onscreen in our study. However, there was no statistically significant difference in reading speed between the text presented in 10 point font and 12 point font sizes. The results of this study that the fonts of 14 point type were read faster than 10 or 12 point type is not surprising. It is logical to assume that moderately larger typefaces will be read faster because of the availability of a larger matrix of pixels for each letter to be defined and also because each glyph /character uses a larger degree of the visual arc [29]. There are a predetermined number of rods and cones in the human eye to interpret visual symbols such as type glyphs. Moderately larger type, such as that used in this experiment, will result in more optical receptors being used for reading an onscreen glyph. It is well documented that larger text is read faster and is therefore more legible. Geske [11] found that speed of reading increases for type larger than 12 points. In the present study we have observed that, the subjects preferred Sans serif fonts more than Serif fonts and the ranking of their choice of font type was greater for Verdana and Arial, which are very common Sans serif fonts. Similar was observed by the others [3, 14-15]. In this respect Rubinstein [30] stated that when typefaces are digitized for use on computers, the letter forms have to fit within a relatively small pixel grid, often leading to what are called the "jaggies". Many web professionals such as graphic designers claim that this relatively low resolution cannot render effectively enough the fine finishing strokes of Serif typefaces, and that Sans serif typefaces tend themselves more naturally to being digitized, and come out cleaner and thus more legible. This has been further supported by the fact that, subjects in our study ranked Verdana 14 as preferred font type and size combination, followed by Arial 14. When used at very small sizes Serifs may actually become visual noise causing detraction from the main body shape of the letter form [31]. This view has also been supported by present study. In our study, it has been observed that in 10 point size subjects did not like to read Serif fonts at all. According to Poulton [32] and Reynolds [26], other factors such as stroke thickness, counter size and x-height are likely to have a far greater effect in preserving the overall identity of a letter form. San serif fonts possess greater x height and stroke thickness and so it is more legible than Serif fonts. More recent studies have shown that computer users prefer Sans serif typefaces for body text online [3, 14-15, 26].

This finding of preference for Sans serif than Serif has also received support from the results of overall mental workload. Overall mental workload during reading was significantly least for Verdana 14 point, followed by Arial 14 point. This indicates that the overall mental workload was significantly less for Sans serif font type and size combination compared with Serif font type and size combination. Subjects felt

more relaxed during reading Sans serif fonts than Serif fonts. It may be due to more space between two letters in Sans serif fonts (particularly in case of Verdana and Arial) which may help to identify the letter easily and make it more legible. The increased legibility of Verdana is also supported by the study of Sheedy et al. [29], who found Verdana as most legible for both capital letters and words and TNR as the worst. In the present study, we have observed that subjects selected Verdana as the best font type, followed by Arial in terms of their ranking and level of mental workload. Interestingly, another Sans serif font which is also being widely used such as Tahoma, was least preferred by the subjects and they ranked it on a negative scale. This has raised doubt that whether generalized statement about font type legibility in terms of only Serif or Sans serif family is possible or not. Sheedy et al. [29] stated that, it is not possible to generalize one category of font as more legible than others and so the legibility of each font would need to be determined separately, but not as a whole.

The results of this study help us to draw following inferences which should be restricted to the population and age group studied for onscreen reading of text. For font type legibility Courier New 14 point font is best as it promotes faster reading than any other font type and size combination studied in this experiment. Serif fonts were read faster than Sans serif fonts. Most preferred font type and size combination was Verdana 14. Overall mental workload was least for this combination only. It was followed by Arial 14 point. Serif fonts were less preferred than the Sans serif fonts. For the font size preference 14 point size was more preferred than the 12 point. Verdana was considered by the users as most preferred font type followed by Arial.

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