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Research Article

Does Changing the Font Type Affect the Processing of Words Written in Cyrillic and Latin Alphabet?

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ABSTRACT

To understand the reading process, it is necessary to explore the mechanisms of visual word recognition. The basic level of that recognition is the processing of letters, their size and visual identity. The specificity of the Serbian language is characterized by the parallel use of two alphabetic systems – Latin and Cyrillic, which contain a number of common, but also their own unique letters. Since some of the differences between the fonts are based on visual specific aditions at the end of letter's lines, there is also a significant contribution of fonts in letter recognition and reading. The main goal of this study is to examine the effect of font type on the processing of Latin and Cyrillic words. The aim was also to examine the effect of letter degradation on the word processing in these two alphabetic systems. The study included two experiments with Latin and Cyrillic words written in lowercase and uppercase. Participants were 221 students from the University of Banja Luka. Three factors were varied in both experiments: alphabet, "visual availability" (which refers to the visibility of words after degradation), and font type. Two analyses were performed ANOVA by subject (F1 analysis) and ANOVA by item (F2 analysis). Results show that there is a main effect of visual availability on processing speed of words. Visual degradation has slowed reaction time, but this effect is not the same in Latin and Cyrillic words. Significant interaction of font and alphabet is confirmed only in F2 analysis, so these results have limited validity. This study also revealed differences between lowercase and uppercase. Degradation of lowercase was more detrimental

that degradation of uppercase. The obtained results indicate that word processing in two alphabetic systems can be partly explained by the visual characteristics and grapheme structure of their letters.

Key words: Latin alphabet, Cyrillic alphabet, font, visual degradation, grapheme characteristics

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Introduction

Reading is a process that allows us to adopt a significant amount of information. But reading efficiency depends on a variety of factors. It is determined by the limitations of the human information processing system, but also by factors related to the characteristics of the text being read. Thus, it was found that the size and proportion of letters, the length of words in the text, as well as the background on which these words are written, significantly affect the readability (Tinker, 1963). A number of studies have also found a significant contribution of the font (Brumberger, 2003; Gasser et al., 2005; Halin, 2016).

The font refers to the letters represented in a particular shape and size. Line extensions and the shape of the letters represent the basic discriminant characteristics of different fonts that can be used to write and transmit information. Therefore, font characteristics should be optimal for reading and recognition. Font types should be different but should also retain the uniqueness of each letter that is particularly important. Font types can be divided into two categories: serif and sans-serif font, which differ in structural details at the ends of the letters. The serif font is characterized by having fine horizontal lines at the top and the bottom of most letters. One of the most representative groups of a serif font is Times New Roman (Hoffmeister, 2016). On the other hand, sans-serif fonts do not have those horizontal lines, as is the case with Arial fonts (Woods et al., 2005). The appearance of Times New Roman and Arial fonts also differs in width in certain parts of the grapheme, that is, in Times New Roman font certain parts of the letter are wider than the other parts of the letter, while in Arial font all parts of the letter are of the same width (Hoffmeister, 2016).

Some studies have shown that speed and accuracy in reading are better with the words written in sans-serif font than a serif font (Dogusoy et al., 2016; Moret-Tatay & Perea, 2011; Moriss et al., 2002; Woods et al., 2005). On the other hand, Banerjee et al. (2011) have shown the opposite results. A small number of studies have examined the effect of the font on the processing of Cyrillic words. A study conducted by Akhmadeeva and colleagues examined the difference in the legibility of Cyrillic words written in serif and sans serif fonts for Russian

Cyrillic readers (Akhmadeeva et al., 2012). They also wanted to explore whether general laws like ecological hypothesis, developed on the Latin typography material, are valid for the Cyrillic script. The results of their study showed no difference in the average numbers of the words read per minute between serif and sans serif variants. Certain differences were determined depending on gender, age, and academic success.

In a series of experiments (Alexeeva & Konina, 2016, Alexeeva et al., 2017, Alexeeva et al., 2019), the authors measured the legibility of Russian Cyrillic letters depending on the font (fixed-size serif Courier New/proportional serif Georgia) in parafoveal vision. Letters were briefly presented in parafovea, either in isolation or surrounded by the asterisks (imitating a letter being within a word), and the participants were asked to name them. The eye-tracking prevented participants from looking directly at the letters. The results showed that Courier New is a less legible font than Georgia, especially when a letter is a part of a sequence. The results support feature-based letter perception inside words. In addition, the first confusion matrices for the Russian alphabet were created based on experiment results. Their analysis revealed that independently of font, letters with ascenders/descenders and round envelopes were the fastest to be recognized whereas letters that contained other letters (т-г) decreased identification accuracy.

A review of previous research shows that a larger number of studies were done in the Latin alphabet compared to the Cyrillic alphabet. The specificity of the Serbian language is reflected in the specific phenomenon of synchronous digraphy, which represents the parallel use of two alphabetic systems - Latin and Cyrillic (Ivković, 2013; 2015). This means that the same word can be written in Cyrillic and Latin. Both alphabets are composed of thirty letters, where each letter is represented by one grapheme, except the letters "lj", "dž" and "nj" in Latin. Several researchers have investigated the differences in the processing of these two alphabets. Some of these studies did not show the difference or dominance of the letters of one alphabet over the other (Ognjenović et al., 1995; Rot et al., 1986), while others did (Rohaček, 1973). Vejnović et al. (Vejnović & Jovanović, 2012; Vejnović et al., 2011) found that the words written in Latin were pronounced

faster than the words written in Cyrillic. On the other hand, Pašić (2004) has shown that the words in Cyrillic are read faster. Šokčević et al. (2013) also found that in the task of visual search of words, the search time is shorter for Cyrillic sets. The advantage of the Cyrillic alphabet was obtained in a study about word recognition conducted by Filipović-Đurđević et al. (2013). These studies clearly show that there are certain differences in the processing of two alphabets in the Serbian language. We wanted to examine whether the visual characteristics of the letters could explain these differences. Certain studies with the same goals have already been done which show that the effect of degradation is not the same in the Latin and Cyrillic alphabets (Borojević et al., 2018; Borojević & Stančić, 2019). In those studies that manipulated the amount of information available in such a way that the lower half, the upper half of the word, or the whole word was visible, it was found that the upper parts of the grapheme and the entire Latin grapheme contain the same amount of information needed for word processing, while lower parts have very low informative value. No such regularity was found for words written in Cyrillic. As an explanation of these results, it is stated that Latin graphemes have fewer line extensions in the upper part, as well as several specific extensions in the upper parts, while the lower parts of a larger number of graphemes have the same shape and are more difficult to distinguish. Since the font refers primarily to the visual aspect of the structural parts of the letter, the aim of this research is to check whether the manipulation of the font will lead to a change in the word processing speed in the two alphabetic systems. Since some of the differences between the fonts are reflected in the appearance of the line ends and the specific additions to them, we also tried to examine the effect of visual degradation in these, for fonts, important segments. This implies that the grapheme structure of the letters differs in these alphabetic systems and by including different fonts, knowledge about the effect of the visual characteristics on word processing will be expanded. Two typical representatives of serif and San-serif fonts were selected – Times New Roman and Arial. This study included two experiments. In one case, lowercase letters were used, while in the other experiment, uppercase letters were used. Numerous studies have shown that there is a difference in the processing of lowercase and uppercase letters, due to the specific appearance but also the

frequency of use (Arditi & Cho, 2007; Smith et al., 1969; Tinker, 1963), so that the relevant findings can be obtained by including both types of letters.

Experiment 1

The main goal of this experiment is to examine the effect of font type on the processing of Latin and Cyrillic words. Since Times New Roman, as a typical representative of serif fonts, has specific horizontal additions at the ends of the lines, it is assumed that they will lead to the facilitation of word processing in relation to the Arial font. As the differences between the fonts are determined partly by these additions at the ends of the lines, we also wanted to examine the effect of degradation in the upper and lower segments of the letters on the word processing in the two alphabetic systems. We assume that degradation will have different effects on the processing speed of Latin and Cyrillic words due to their specific grapheme structure. In this experiment, we used uppercase letters to create stimuli. Although they appear less frequently in written text, uppercase letters have specific visual characteristics that may differ, not only in relation to lowercase letters, but also in relation to which alphabetical system they belong to.

Method

Participants

One hundred and forty-one students from the University of Banja Luka participated in the experiment.[1] Participation in the research was conditioned by the fulfillment of three criteria. These criteria were: Cyrillic was the first learned alphabet, there is no preference for one alphabet in reading and writing (according to the participants' statements), and there are less than 30% errors in

[1] Part of the data collected on a number of respondents from this sample is published previously (Borojević et al., 2019).

the experimental task. All the participants had normal or corrected to normal vision.

Materials and design

Three factors were varied in this experiment: alphabet, visual availability of information, and font type. The alphabet was a between-subjects factor and had two levels - Cyrillic and Latin. Visual availability was also a between-subjects factor and had three levels - visible whole word, visible upper half of the word, and visible bottom half of the word. Although this could be a within-subject factor, we treated it as unrepeatable, in order to reduce the possibility of learning stimuli and getting used to them. Font type was also a between-subjects factor and had two levels – Times New Roman and Arial. The dependent variables were reaction time and a number of errors in the task. The stimuli were 60 words and 60 pseudowords, composed of six letters and written in Times New Roman 48 font. The words were nouns (masculine, nominative, singular).

All nouns had 6 letters, two syllables, and did not contain the letters "lj", "nj" and "dž", because they contain two characters in the Latin alphabet. Noun frequency ranged from 1 to 115 ipm. The average value was 34 (SD = 32.02). All nouns were selected from The Frequency Dictionary of Contemporary Serbian Language (Kostić, 1999). The same stimuli were presented in both alphabets and were written in uppercase letters. They were black, on a white background.

Procedure

The subjects were tested individually and were randomly divided into experimental situations that were created by a combination of three factors (2x3x2). The lexical decision task was used and 120 stimuli were presented in each experimental situation (60 were words and 60 were pseudowords generated in the Wuggy program; Keuleers & Brysbaert, 2010). At the beginning of the experiment, the subjects read the instruction, which said that a string of letters would appear on the screen, and their task was to answer whether the string shown represented a word or a pseudoword. The task started with the fixation point in the center of the screen for 50 milliseconds. After that, a stimulus was

presented at the same position. The participants responded by pressing the appropriate key („R" for word and „P" for pseudowords) on the keyboard. Each participant had 120 trials with an additional six trials for exercise. Response time was measured, as well as the number of errors in the experimental situation. The experiment was carried out using the software package SuperLab 4.5 for Windows (Cedrus Corporation, 2010). After the experiment, all participants completed a questionnaire examining the order of alphabet learning and the preferences for one alphabet in reading and writing. The whole procedure lasted about fifteen minutes.

Results and Discussion

We analyzed reaction times only for correct answers. Approximately 15% of the data was removed. Descriptive statistics are shown in Table 1. Reaction times were log-transformed before ANOVA was applied. We performed ANOVA by subject (F1 analysis) and ANOVA by item (F2 analysis) to examine the effect of three factors on words processing: alphabet, „visual availability" and font. In addition to the main effects, we also tested two-way interactions between all the varied factors.

Table 1

Descriptive statistics of experimental conditions

Alphabet	Visual availability	Font	*M*	*SD*
Cyrillic	VW	TNR	806.72	311.36
		Arial	931.72	376.44
	VB	TNR	1591.74	599.26
		Arial	1625.56	691.16
	VU	TNR	1423.48	608.75
		Arial	1622.90	730.75
	VW	TNR	870.32	357.74
		Arial	789.82	326.78

Latin	VB	TNR	1326.52	580.30
		Arial	1376.01	642.29
	VU	TNR	1437.78	677.70
		Arial	1391.38	638.84

Note. VW-visible whole word, VU-visible upper part of words, VB-visible bottom part of words

F1 ANOVA shows that there is a main effect of „visual availability" on reaction time ($F1$(2,129) =1 04.098, $p < .001$, $\eta p^2 = .617$). Post hoc analysis with a Bonferroni correction revealed that visual degradation significantly increases the processing speed. Reaction time is shorter for visible whole word than for the visible bottom half of the word ($p < .001$) and for words where the upper half was visible ($p < .001$). On the other hand, there is no difference in reaction times between degraded words ($p > .05$). There is also a statistically significant effect of the alphabet on the processing speed of words ($F1$(1,129) = 8.881, $p < .01$, $\eta p^2 = .064$). The response time for Latin words is shorter than the response time for Cyrillic words. Although the effects of these factors are highly statistically significant, the effect sizes are different. "Visual availability" has a large effect, and explained 61% of all variance in reaction time. Alphabet has a small effect size.

F2 ANOVA reveales also significant effect of „visual availability" on RT ($F2$(2,698) = 500.345, $p < .001$, $\eta p^2 = .589$). The distribution of results is the same as in the F1 analysis. The same significant effect is found for alphabet ($F2$(1,698) = 44.540, $p < .001$, $\eta p^2 = .060$), with shorter RT for Latin words. But, F2 ANOVA reveals a statistically significant interaction between alphabet and font ($F2$(1,698) = 15.603, $p < .001$, $\eta p^2 = .022$). Cyrillic words written in Times New Roman are processed faster than the words written in Arial ($p < .05$), while there is no difference in RT between Latin words written in different fonts ($p > .05$) (Figure 1). The initial hypothesis about processing facilitation due to specific additions in the Times New Roman font was confirmed only for Cyrillic letters, although this outcome has a trivial effect size.

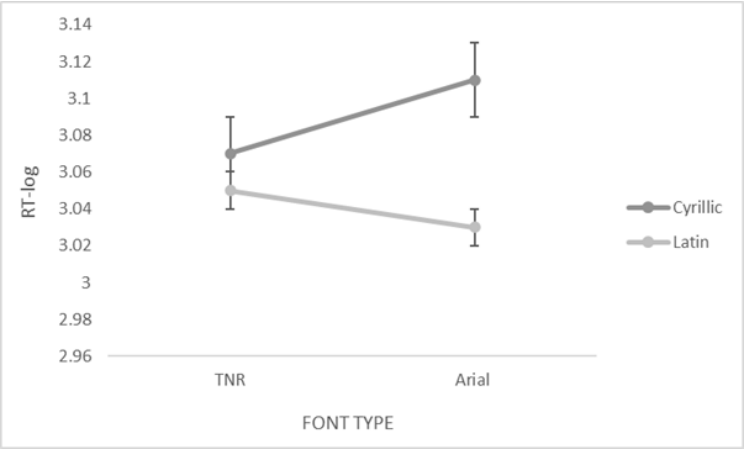

Figure 1. Reaction time depending on the font and alphabet.

Results also show that interaction between the alphabet and "visual availability" is also significant ($F2(2,698 = 6.820$, $p < .01$, $\eta p^2 = .019$). Visual degradation has slowed word processing (Figure 2), but visual availability of only the lower part of letters is more detrimental for Cyrillic than for Latin words. Non-degraded Cyrillic words are processed faster than words with the upper part visible ($p < .001$) and words with the lower part visible ($p < .001$). But there is also a difference with degraded Cyrillic words. Words with the upper part visible are processed slower than words with the lower part visible ($p < .05$). In Latin words, results show that reaction time is shorter for non-degraded words than for words visible in the upper part ($p < .001$) and words visible in the lower part ($p < .001$). But no differences in processing speed were found between the degraded Latin words ($p > .05$). Based on the obtained results, conclusions can be generalized about the effects of the alphabet and „visual availability" on words processing speed, because they are confirmed in F1 and in F2 analysis. But the effect of the font is significant only in F2 analysis, so the results can be limited only to the set of stimuli applied in this study.

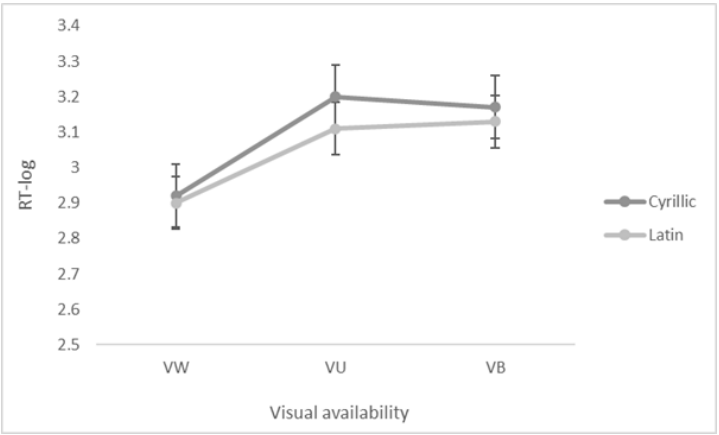

Figure 2. Reaction time depending on the alphabet and visual availability of words

Note. VW-visible whole word, VU-visible upper part of words, VB-visible bottom part of words.

Experiment 2

The aim of this experiment, the design and procedure were the same as in the previous experiment. A new group of subjects was randomly assigned to experimental situations. The final sample consisted of 80 subjects who met the same criteria as in the first experiment[2]. The only difference was in the type of stimuli. The lexical decision task was applied to the words and pseudowords written in the lowercase letters.

Results and Discussion

As in the first experiment, three factors were included in the analysis (alphabet, "visual availability" and font). But, for the Cyrillic alphabet, two levels of the "visual availability" factor had to be excluded from further statistical analysis due to a large number of errors (in this and in the previous study). A large number of errors in these experimental situations indicate that the informativeness of these

[2] Part of the data collected on a number of respondents from this sample is published previously (Borojević & Stančić, 2018).

parts of lowercase letters is higher compared to other parts, so their removal makes processing more difficult. For this reason, we did the analysis only for non-degraded words. Descriptive statistics are shown in Table 2.

Table 2
Descriptive statistics of expermental conditions

Alphabet	Font	M	SD
Cyrillic	TNR	882.49	352.68
	Arial	807.76	223.23
Latin	TNR	981.61	401.02
	aRIAL	922.67	398.51

We only included RT for correct answers in the analysis. Data were transformed by taking log-transformation and two separate analysis were run, ANOVA by subject (F1) and ANOVA by item (F2). F1 analysis did not reveal any significant effect of a varied factor on processing speed. But in F2 analysis results showed that there is the main effect of the alphabet on RT ($F2(1,235 = 20.309$, $p < .001$, $\eta p^2 = .080$). Latin words written in lowercase are processed slower than Cyrillic words (Figure 3). The main effect of font is also statistically significant ($F2(1,235 = 4.672$, $p < .001$, $\eta p^2 = .019$). The words written in Arial font are processed faster than Times New Roman, but the effect size is trivial (Figure 4).

Although certain differences were found in this experiment with respect to the font type, the results obtained are limited to the stimuli used in this study.

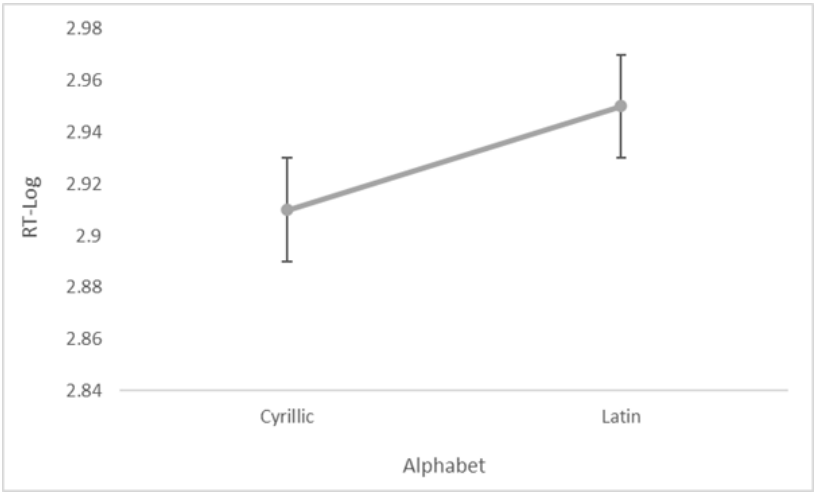

Figure 3 . Reaction time depending on the alphabet

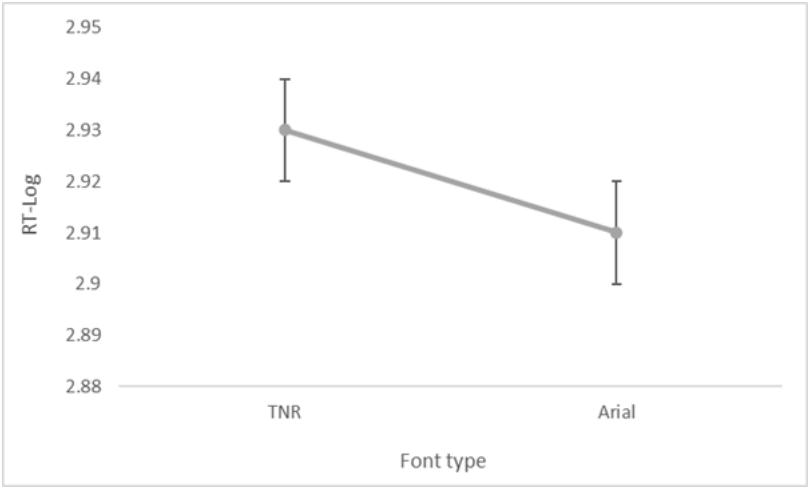

Figure 4. Reaction time depending on the font

General discussion

This research was conducted to examine whether the change in font affects the processing speed of Latin and Cyrillic words, given that fonts differ in visual properties. Previous two studies with degradation of graphemes

(Borojević et al., 2018; Borojević & Stančić, 2019) found a difference in the processing of Cyrillic and Latin words. It has been found that certain parts of the letter, viewed through a frame of horizontal asymmetry, are more informative than others. Arial font was used in those studies, but a few studies show that different fonts can improve or slow down the speed of letters and word processing (Dogusoy, et al., 2016; Moret-Tatay & Perea, 2011; Moriss et al., 2002; Pelli et al., 2006; Woods et al., 2005). We assumed that the words written in Times New Roman font would be processed faster because they contained specific additions in the form of small strokes at the end of the letters. This is partially confirmed only for the Cyrillic alphabet and for the words written in capital letters.

However, such conclusions are limited only to the stimuli selected for this study. With that limitation, it could be said that these results are in line with previous research, whose basic conclusion is that serif fonts contain letters that are more different from each other and allow faster reading with less fatigue (Bernard et al., 2003; Lannon, 2000; Mansfield et al., 1996). Serifs in Times New Roman also make it easy to point out the ends of letters and make identification easier. Those horizontal serifs that are positioned along the font baseline make it easier to track that line and read faster (Arditi & Cho, 2007). The results are also consistent with the findings of the research that was focused only on the Cyrillic alphabet (Alexeeva et al., 2019), which showed an advantage of serif fonts in recognizing letters and words. As this was not confirmed on the Latin stimuli, it could indicate that the visual representations of the letters in the two alphabets are unequal, and cause processing differences. But the differences found in processing speed depending on the font type are not so strong (according to the effect size). Serif as a small ornament at the end of the letter can be informative enough to lead to easier identification, but the amount of visible information seems to be more important. Removing the upper or lower parts of the letters significantly reduces the reaction time, regardless of whether they are written in TNR or Arial font.

In the experiment in which the stimuli were the words written in lowercase letters, the obtained results completely deviate from the initial

hypothesis. However, before the explanation of these results, it should be noted that due to a large number of errors, it was impossible to analyze certain experimental situations (those related to visual degradation). Visual degradation had such a pronounced negative effect that it was practically impossible to process the words accurately. Therefore, these experimental situations were excluded. It seems that in lowercase letters the individual segments of lines located in the upper or lower half contain a greater amount of information than in the case of uppercase letters. Obviously, the processing of lowercase and uppercase letters is not equally demanding, which has been confirmed by previous studies (Arditi & Cho, 2007; Smith et al., 1996; Tinker, 1969). Lowercase letters are commonly used, and this is why some authors consider them better stimuli (Sanocki & Dyson, 2012). Furthermore, lowercase letters differ in size and specific parts, the so-called ascenders, and descenders, which makes them more discriminable than uppercase letters that are the same size. The removal of these ascenders and descenders in this and in the previous study actually inhibited this letter discrimination. On the other hand, it was found that the words written in lowercase were processed faster in Arial font compared to Times New Roman. But, as in the first experiment, only one analysis conducted by items revealed these results, so we can not generalize it. Although the data are unexpected and have limited validity they could be explained by the interpretation offered by Woods et al. (2005). In a study they conducted in order to compare the legibility of lowercase letters in two different fonts, the advantage of the Arial font was also determined. The authors attributed this advantage to the font size. Arial's x-height (the distance between the baseline and the top of the main body of lowercase letters) is larger than Times New Roman's in the same point size, which makes Arial more legible. They also pointed out that Arial has a uniform stroke width, which increases its legibility.

Conclusion

This study has shown a particular effect of font type on word processing speed in the Serbian language. But this effect is weak and not the same in the Cyrillic and Latin alphabet. We selected Times New Roman and Arial as the two

representatives of serif and sans serif fonts. TNR is more frequent, and it is the most used font in written media. If we conducted research on another font that was designed for reading from the screen (such as Georgia) we might get a clearer perspective on the relationship between font and word processing in two alphabetic systems in the Serbian language. On the other hand, visual availability has shown a strong influence on processing speed. The degradation of letters had a very detrimental effect on word recognition. Therefore, further research should be taken in order to examine whether the difference in word processing can be explained by the visual characteristics of the letters. Instead of analyzing the upper and lower parts of the letters, research can also be shifted to a more specific, molecular level. It is necessary to determine whether certain structural parts of the letters (such as terminations, intersections, or curves) are more important for their processing and whether they differ in the Latin and Cyrillic alphabet.

Conflict of interest

We declare that we have no conflict of interest in submitting the manuscript "Does changing the font type affect the processing of words written in the Cyrillic and Latin alphabet?" in Primenjena psihologija.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Da li promjena tipa fonta utiče na obradu latiničnih i ćiriličnih riječi?

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SAŽETAK

Da bismo razumjeli proces čitanja, neophodno je istražiti mehanizme vizuelnog prepoznavanja riječi. Osnovni nivo tog prepoznavanja je obrada slova, njihove veličine i vizuelnog identiteta. Specifičnost srpskog jezika karakteriše paralelna upotreba dva alfabetska sistema – latinice i ćirilice, koja sadrže niz zajedničkih, ali i svojih jedinstvenih slova. Pošto su neke od razlika između fontova zasnovane na vizuelnim specifičnim dodacima na kraju linija slova, postoji i značajan doprinos fontova u prepoznavanju i čitanju slova. Osnovni cilj ove studije je da se ispita uticaj tipa fonta na obradu latiničnih i ćiriličkih riječi. Cilj je takođe bio da se ispita efekat degradacije slova na obradu teksta u ova dva alfabetska sistema. Studija je obuhvatila dva eksperimenta sa latiničnim i ćiriličnim riječima ispisanim malim i velikim slovima. Učestvovao je 221 student Univerziteta u Banjoj Luci. Varirana su tri faktora u oba eksperimenta: pismo, „vizuelna dostupnost" (koja se odnosi na vidljivost riječi nakon degradacije) i tip fonta. Urađene su dvije analize ANOVA po subjektu (F1 analiza) i ANOVA po predmetu (F2 analiza). Rezultati pokazuju da postoji glavni efekat vizuelne dostupnosti na brzinu obrade riječi. Vizuelna degradacija je usporila vrijeme reakcije, ali ovaj efekat nije isti u latinici i ćirilici. Značajna interakcija fonta i alfabeta potvrđena je samo u analizi F2, tako da ovi rezultati imaju ograničenu validnost. Ova studija je takođe otkrila razlike između malih i velikih slova. Degradacija malih slova je imala negativniji efekat od degradacije velikih slova. Dobijeni rezultati ukazuju da se obrada teksta u dva alfabetska sistema djelimično može objasniti vizuelnim karakteristikama i grafemskom strukturom njihovih slova.

Ključne riječi: latinica, ćirilica, font, vizuelna degradacija, grafemske karakteristike